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CONSERVATIVE INNOVATORS AND MILITARY SMALL ARMS: AN INDUSTRIAL HISTORY OF THE SPRINGFIELD ARMORY, 1794-1968

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This report is perhaps best described as a case study in American industrial history, treating the Springfield Armory as a very unusual factory system. Through most of its history, the Armory had one customer and one principal job: to supply the U.S. Army with reliable, powerful shoulder arms. In this role, Springfield's longstanding—if uneven—federal funding through many economic crises, the peculiarities of Army small arms demands, and, perhaps, the power of Armory workers in shop management all contrast with the histories of most private industries. If unusual, however, the Armory was hardly irrelevant or tangential to the development of American industry, especially prior to the Civil War. Historians have long recognized this government factory's central place in economic and industrial history, and if anything have often overstated the case. The lack of any comprehensive study of Springfield Armory has therefore been something of a gap in that history, a gap which we are bridging—although not filling--with this report.

As a research subject, the Armory is better characterized as an abyss than a gap. When closed in 1968, the Armory was probably the longest continuously-operated industrial facility in the United States, with a history of over 170 years, and had generated enormous quantities of paperwork and artifacts which remained available for study. Here again, government management practices were unusual among antebellum American industries, leaving Springfield as one of the best-documented factories of the period. In the 20th century, the growth of Army and other government bureaucracy accelerated the generation of documents, to such an extent that detailed study of events after 1945 is often an act of self-immolation.

Our first debts as authors are to the very few scholars who have previously emerged intact from prolonged exposure to Springfield Armory data with useful, if partial, monograph treatments of Armory history. Without their works, it is doubtful we could have completed this one in any reasonable period of time. Given the difficulties in editing the results of immersion in thousands of letters and reports, it is probably no accident that some of these works have never been published. Derwent Whittlesey's 1920 dissertation mastered the complexities of Armory political history and local controversies through the Civil War. Constance Green, during her employment at Springfield as a historian during World War II, combined documentary and informant research to produce a more comprehensive manuscript chronicling Armory history through the Civil War, and from 1919 to 1944. Edward Ezell has spent much time during the past twenty-five years finding the story of post-1945 rifle development in the thicket of Army paperwork and the memories of those most

directly involved, eventually producing an excellent book. Merritt Roe Smith's widely-recognized books and articles since the early 1970s on Harpers Ferry Armory, the Ordnance Department, and 19th-century small arms makers have included extensive use of Springfield Armory correspondence. Finally, Felicia Deyrup's pioneering 1948 publication on pre-1870 Connecticut Valley arms makers relied heavily on Armory records, and proved extremely pertinent to our final selection of topics and issues.

The National Park Service's principal objective in contracting for this study was coverage of the entire period of Armory operation, and assessment of Springfield's place in American industrial and military history. Given the wealth of Armory data and the Park Service's available resources, we had to make careful decisions on the scope and organization of this report while meeting this objective. In following the story of how the Armory's industrial practices met Army Ordnance Department requirements, we have largely ignored its role in local and regional economics, politics, and social organization. Although partially treated in the work of Whittlesey, Green, and Deyrup, and in some local histories such as Michael Frisch's, the Armory's place in the Springfield region has never been thoroughly analyzed, and to have done so would have pulled us onto a largely separate and very long research path. Somewhat similarly, we have made only preliminary attempts to trace or define the Armory's influence on private American industry, since the availability of pertinent, detailed comparative studies or case histories remains limited. It is clear from our work, however, that the military demand for interchangeable small arms led to a factory system of enormous but very specialized strengths, with less widespread applicability than sometimes believed. Our conclusions here agree with those of Donald Hoke's 1984 dissertation, but the subjects of both the Springfield region and the Armory's influences are still very open ones for ambitious researchers.

As to how we have concentrated our efforts, two decisions were paramount: organization of the report, and selection of research material. After considering a combination of chronological and interpretative chapters, we opted for a more thematic or topical approach, corresponding in part to how we had to unravel the Armory as an industrial system. Each major aspect of Armory operations--physical plant development, materials management, organization of labor, mechanization and manufacturing, and research and development—appears in a separate chapter (Chapters 4-8) covering the entire period 1794-1968. To explain why these operations took their particular historical forms, chapters 2 and 3 discuss military demands, the weapons which were the

Armory's principal products, and the extraordinary emphasis on making these weapons interchangeable. Chapter 1 throws a chronological net over all these topics, to capture a more unified picture and guide the reader through the following seven chapters. Following our version of what the Armory actually did, and why it was done, chapters 9 and 10 offer summary interpretations of Springfield's place in American economic and military history. We recognize that this approach necessarily creates some redundancies in presentation, although long-term trends in Armory operations sometimes appear more clearly this way. Of equal importance, it became clear that, since effective use of a largely chronological organization would have required the same assimilation of the principal topics, we would have had to write this report twice. We will, in fact, try it again the other way, but as a separate published book.

In selecting research material, our basic approach was to assemble what was already available on our topics, identify what was missing or less than convincing, and fill in the gaps with primary research. In addition to the works of the authors already mentioned, there are hundreds of books, articles, and unpublished papers pertaining to Springfield Armory. Collectively, we read most of them. We rechecked original correspondence cited in the works of Whittlesey, Green, and our colleague Merritt Roe Smith as needed, but only made new ventures into the mass of these traditional primary sources for information on poorly documented points. Since letters and government reports rarely told us what was actually happening in Armory shops, we relied on more direct sources. The availability of detailed work returns and payrolls, extremely rare among 19th century American factories, gave us itemized data on the organization and productivity of Armory workers. We also used material evidence, in the form of finished weapons, unfinished parts, and gages, available at the Springfield Armory Museum, the National Museum of American History, and some private collections. The artifacts, which included weapons made at other public and private armories, provided many new insights into the ways Springfield armorers actually made their weapons, the extent to which their work reflected Armory standards of interchangeable manufacture, and the relative quality of their work among contemporary arms makers.

Many of our more original conclusions emerged directly from use of the accounting data and the artifacts, suggesting the wide range of sources and approaches needed in industrial history or archaeology. Budgetary constraints, copyright problems, and Park Service priorities have limited some other approaches which would otherwise have improved our presentation. Even with the alteration or removal of some Armory buildings since 1968, there is clearly much to be learned from

more detailed inspection of surviving structures than we were able to make. Reproducing historic views or other illustrations of the Armory, its workers, products, or tools would have made the report somewhat more accessible, but at costs to a budget we soon found completely absorbed by research and writing. We regret not illustrating Springfield weapons, but most available illustrations--and many are published--do not show working parts well enough to enhance discussions of manufacturing problems, and the very few which do were encumbered by copyright issues too time-consuming for the scope of our contract.

Collectively or individually, we have received valuable help from many people. The National Park Service staff at Springfield Armory National Historic Site provided materials and suggestions without which our work would be less than it is. In particular, we thank curators Stuart Vogt and William Meuse, mechanic Richard Harkins, and historian Larry Lowenthal. North Atlantic Regional Historian Dwight Pitcaithley provided much contractual forbearance, and advice on matters of report format and copyrights. We had the help of several experienced reviewers and guides, especially historian Merritt Roe Smith and engineer/arms collector Lennox Beach, whose patience with our progress was as commendable as their actual assistance. Hugh G.J. Aitken and Russell Fries had similar roles during early stages of our work. Other historians, archaeologists, arms collectors, curators, and skilled mechanics that helped us included Edwin Battison, John Bewitch, Arthur Brooks, Arthur Goodhue, Harry Hunter, Burton Kellerstedt, Larry Lankton, Thomas Leary, Frank McKelvey, Vance Packard, Bruno Pardee, Theodore Penn, Matthew Roth, Euan Somerscales, David Starbuck, Robert Vogel, and Dennis Zembala.

Springfield Armory products deserve one final comment. Although ours is more an industrial than a military history, relatively few industrial products are intentionally used to kill or wound hundreds of thousands of people. We brought a wide range of experience and views on matters of war and peace to our work, but remain silent in this report on the uses to which the Armory's often astonishing mechanisms were ultimately put. Readers may provide their own views on the ancient issues of technological progress, government expenditure, and war.

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INDUSTRIAL HISTORY AT SPRINGFIELD ARMORY: AN OVERVIEW

Springfield Armory has had an almost legendary status in American history for many years. It is usually associated with two major accomplishments: design and production of the most important shoulder arms used by the United States Army from the 1790s to the 1960s; and early 19th century innovations in interchangeable manufacture of complex metal and wood products, and in organization of factory production.[1] It is rarely associated with manufacturing innovations made after the Civil War, although its twentieth century production of high-quality magazine and semi-automatic rifles won enduring places in the hearts of infantry veterans and gun collectors. This report focuses on manufacturing issues at the Armory during its long history. We contradict or at least qualify some of the conventional wisdom about the Armory's largely unwritten history, such as the notion that the achievement of interchangeable manufacture was synonymous with completely mechanized operations, or the idea that the Armory's work after the Civil War is of little interest to industrial historians. This chapter introduces Springfield Armory history, and discusses the relationship of the Armory's main task -- making military muskets and rifles -- to approaches to innovation which ultimately affected the Armory's fate as a government-operated factory.

Armory Products and Military Industrial Demands

The Armory made five major types of shoulder arms between 1795 and 1963. Single-shot, smoothbore flintlock muskets, based on late 18th century French models, were the earliest and longest-made, produced at Springfield in several variations between 1795 and 1842. Private contractors and the national armory at Harpers Ferry, [West] Virginia also made flintlock muskets for the Army during this period. Similar weapons, with locks adapted to percussion ignition of ammunition, were produced at Springfield as smoothbore muskets from 1844 to 1855, and as rifle-muskets from 1857 to 1865. Breechloading rifles, made from 1865 to 1893 with a so-called trapdoor mechanism, were the third major weapon type and the final variation on Springfield single-shot shoulder arms. These earliest three types were in many ways the same design, with different firing mechanisms and different means of making the barrels. Beginning in 1893, the Armory

[1] Alfred D. Chandler, Jr., The Visible Hand: The Managerial Revolution in American Business , pp. 72-5; David A. Hounshell, From the American System to Mass Production, 1800-1932, pp. 32-46.

concentrated on fundamentally different rifles which comprise the last two major weapons types. First, the Armory made two types of bolt-action magazine, or repeating, rifles as standard infantry issue until 1931. These included the so-called Krag rifle, based on a foreign design, and the Model 1903 Springfield rifle designed at the Armory. The manufactured quality of the latter weapon, used in World Wars I and II, was unsurpassed among contemporary military small arms. There were no newly-manufactured rifles made from 1931 to 1937, as the Armory prepared to make a new generation of weapons. The fifth type of rifle, in which combustion gas from fired cartridges operated the breech mechanism, included the semi-automatic M1 Garand rifle made from 1937 to 1957, and the selective-fire full automatic M14 made from 1959 to 1963. During World War II, inventor John Garand's M1 had more fire power than any available, standard-issue military rifle in the world.

At a minimum, small arms manufacture usually requires a wide variety of raw materials, tools, and fuel sources; sufficient power to operate at least forges and trip- or drop-hammers; and a large number of disparate operations on wood and metal components. The traditional division of lock, stock, and barrel has always defined the principal manufacturing as well as functional distinctions for shoulder arms. The lock, or any of the later firing mechanisms, consists of many small, precision-made metal components capable of withstanding powerful mechanical stresses. The stock, until recently always wood, requires a properly dried, very tough hardwood block or rough form, and careful cutting of irregular or curved surfaces to accommodate the firing mechanism and barrel. Barrel-making requires iron or steel capable of withstanding the explosive forces and heat of fired ammunition; shaping, rolling, or welding of a metal tube unless solid bars are used; precision boring, rifling, or drilling; and surface smoothing.

The demands of military small arms manufacture on an industrial scale, and the time and place of early Springfield Armory history, were decisive influences on Armory manufacturing practice. Although other American industries before 1840 had some of the same manufacturing and material problems, none had such a wide range of demands, and when the Armory began operations there was virtually no machinery available for any of the work. Very few private arms makers could even attempt to make arms along accepted military lines with predictable quality. The government realized in the 1790s that reliance on neither private domestic suppliers nor purchase of imports,

which could be halted during international conflicts, was sufficient to arm the nation in a crisis. A Congressional act in 1794 empowered President Washington to establish several national armories for manufacture of small arms for the Regular Army.[2] The government plants had to rely initially on craft production, using imported designs, so that purchase of arms remained important for another generation, until Army ordnance officers and mechanics gradually created industrial plants and methods capable of making acceptable weapons.

Reaction against early Federal period problems in small arms procurement spurred Army demands for weapons which were of consistent and high quality. As we outline below, these demands centered on production of weapons perceived as uniform and interchangeable. Springfield Armory met these demands, reaching extraordinary levels of industrial organization and quality control by the Civil War. Continued insistence on methods which met antebellum Army demands maintained early standards during later periods, but at costs in production efficiency which left the Armory unable to deal with all ramifications of small arms procurement in 20th century wars.

Springfield Armory Before 1815

President Washington chose national armory sites at Springfield, Massachusetts and Harpers Ferry, Virginia. Harpers Ferry, selected largely for sectional and other political reasons, had abundant water power but no prior record as an arsenal or arms factory. With the notable exception of John Hall's work in making early interchangeable, breech-loading rifles, Harpers Ferry Armory rarely reached the production levels, or initiated the mechanical or organizational developments, seen at Springfield. Both armories remained the only federal small arms factories until the Civil War, when the destruction of the Harpers Ferry site left Springfield as the only national armory into the very early twentieth century.[3]

The Springfield site in 1794 was an unlikely industrial center. As a federal installation, it began as a Revolutionary War storage and supply depot, responsible primarily for repairing small arms, making gun carriages and musket cartridges, and storing powder and various war materiels. Continental war

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[2] Edward C. Ezell, "The Development of Artillery for the United States Land Service before 1861," pp. 49-76; Merritt R. Smith, Harpers Ferry Armory and the New Technology, p. 28.

[3] Smith, Harpers Ferry, provides extensive comparisons of the two armories. For ready comparison of each armory's output, cf. his Table 1 with Felicia J. Deyrup, Arms Makers of the Connecticut Valley, p. 233.

planners saw Springfield's position, more than 60 miles up the Connecticut River, as secure from potential naval assault, and the presence of at least some gunsmiths as a promising labor force. From 1782 to 1794, the depot served as a public magazine for storage of arms and powder. As one of a few such federal installations, the depot become the core of the Armory, more or less on the basis of existing if somewhat flimsy facilities. The depot took root on Springfield's town Training Field, which the Continental Congress leased from the town as a matter of convenience. The site was well above the river town east of the Connecticut River, on a rather steep-sided plateau far from any water power sources. A more promising industrial site for the Armory on the west side of the river was eliminated by local opposition to the possibility of unruly mechanics disturbing a farming community.[4]

By 1794, there were perhaps a dozen frame workshops and storage buildings, defining the east, south, and northeast sides of what became known as Armory Square, with some structures in the middle of the square. A brick magazine for powder storage, built well east of these buildings, was the principal addition between 1781 and 1794. We know little about the workings of the Revolutionary War or early Federal depot, although many of the same buildings as well as some barracks became early Armory shops, generally defining a spatial pattern which persisted throughout most of the Armory's history: manufacturing operations on the east and northeast sides of Armory Square, storage or arsenal facilities on the south side, and barracks or officers' quarters on the north and northwest sides. After a fire cleared the quadrangle interior of structures in 1801, this space remained open and evolved with the buildings on the outside in a familiar military pattern.[5]

Early Armory managers moved quickly to provide waterpower and more facilities, purchasing in 1795 the Training Field and the first of an eventual four sites on the Mill River, a mile south of the Training Field. The basic division between the Hill Shops, as the original plant came to be known, and the Water Shops remained a permanent challenge to Armory managers. The distance between the Hill and Water Shops, and among the Water Shops themselves, created a great deal of hauling

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[4] Derwent S. Whittlesey, "A History of the Springfield Armory."

[5] All statements made here and below concerning Springfield Armory plant development are based on collation of data in numerous maps on file at SANHS, in Whittlesey, in annual reports of Springfield Armory operations in various formats beginning 1845, and in Constance M. Green, "History of Springfield Armory."

between different manufacturing steps (Figure 4.1). There were other problems inherent in Armory siting. The Mill River was a limited waterpower source, inhibiting early mechanical operations and requiring somewhat haphazard dispersal of different musket-making operations. No single site available to the government could accommodate all Armory requirements.[6]

Some of the first Armory superintendents, notably Benjamin Prescott (in charge November 1805 - August 1813), began to impose a division of labor on this complicated situation after about 1805, establishing separate shops for separate operations. Limited physical facilities, and dispersed millseats, did not allow for complete or effective division by task.[7] Sporadic beginnings of mechanization accompanied early Armory growth, as Watershop operations by 1815 included limited milling and slitting of some screws and lock components; boring, grinding, and polishing of barrels; and possibly trip-hammers for the difficult hammering and welding of iron sheets into rough barrels.[8] The Watershops through the first half of the 19th century were relatively small structures, reflecting the waterpower limitations. After 1808, when Prescott obtained the third and uppermost millseat, these and all other new Armory manufacturing facilities were built of stone, brick, or other fire-resistant materials. All hand- or foot-powered work was concentrated in a few shops at the east and northeast sides of Armory Square on the Hill, including forging and filing of most lock components and other small metal parts needed to hold a musket together, and stock-making prior to the introduction of Thomas Blanchard's waterpowered machinery around 1823.

Prescott's initiatives also included the beginnings of a comprehensive record-keeping system, organized on a monthly basis by workshop, which helped regulate costs and productivity.[9] Under his charge, Armory musket production nearly tripled, to more than 10,000 per year in 1812 (Figure 1.1). Yet Armory operations before 1815 had serious policy and organizational problems, as well as siting difficulties and limited mechanization, which inhibited weapons production. There were few standards for small arms manufacture, a number of private arms makers and suppliers who increased

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[6] Robert B. Gordon, "Hydrological Science and the Development of Waterpower for Manufacturing."

[7] Springfield Armory Work Returns, 1806-1815, in RG 156/1371.

[8] John Whiting to William Eustis, January 13, 1810, Records of the Office of the Secretary of War, National Archives (Record Group 107), Washington, D.C.

[9] see n. 7 above.

the variations in arms quality, and no central direction or oversight of procurement and manufacture. The Secretary of War was in charge of several conflicting lines of authority in these matters, and the Armory superintendents could not even control their own supplies. As the War of 1812 began, Congress authorized creation of an Army Ordnance Department to oversee procurement and inspection of cannon, and inspection of manufactured or purchased small arms. A Commissary-General of Purchases directed actual small arms manufacture and purchase, however. In the confusion which followed, the Armory spent more time repairing older, poorly made weapons than it did making better new ones. Arms procurement in general was so chaotic during this war that the head of the Ordnance Department, Col. Decius Wadsworth, was able to gain control of all Army ordnance, including management of the national armories, within several months of the war's end.[10]

New Directions and Priorities, 1815-c1830

Reorganizing small-arms procurement was an immediate post-war Ordnance Department priority, and department responses had extremely important implications for all subsequent Armory history. There was an acute awareness of the need for reliable weapons, but this need took a particular turn at this time. By 1815, Ordnance Department officers with artillery backgrounds were fascinated with making uniform arms, meaning to them weapons with dimensionally interchangeable parts. Uniformity was an ideal promoted after about 1760 by French artillery officers, some of whom had become American ordnance officers. Some small-arms makers like Eli Whitney were aware of Honoré Blanc's laborious but apparently successful French attempt to make muskets with interchangeable lock parts, an achievement promoted for American adoption by Thomas Jefferson.[11] Believing that interchangeable weapons would mean easier field repairs and cheaper manufacture, the officers running the Ordnance Department urged development of uniform small arms, with detailed written specifications and gages for inspection purposes. Their enthusiasm helped promote Congressional support for the armories.[12]

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[10] The history of Army ordnance procurement during and immediately after the War of 1812 is extremely complicated, incompletely documented, and at times difficult to interpret. For summaries which convey the sometimes fabulous disorder of the period, see Smith, Harpers Ferry, pp. 53-106; Ezell, "Artillery," pp. 77-87; James A. Huston, The Sinews of War, pp. 103-104; and Russell F. Weigley, History of the United States Army, enlarged edition, pp. 108-24.

[11] William F. Durfee, "The First Systematic Attempt at Interchangeability in Firearms," pp. 475-6.

[12] The best recent treatment of early Ordnance Department objectives and policies is Merritt R. Smith, "Army Ordnance and the 'American system' of manufacturing, 1815-1860."

Those in the department directly responsible for making small arms, however, were far more cautious about the goal of uniformity, recognizing in particular the difficulty of making interchangeable locks unless the gages and components were durable enough to resist wear. Since the Armory superintendents had to develop, find, buy, or borrow the methods of manufacture, and since their superiors knew little about such matters in this period, the superintendents and their principal mechanics and armorers really determined the initial pace and direction of uniform small-arms manufacture. The men at Springfield were apparently more concerned with improving the quality of arms made by the national armories, and by the contractors upon whom the Ordnance Department still had to rely for some arms, than with possible savings in costs or repair time. The arms makers were more realistic than their superiors: interchangeable manufacture proved to be costly and unrelated to rapid field repairs. Regardless of reasons, however, the Ordnance Department as a whole directed almost thirty-five years of sustained effort at making essentially uniform muskets, succeeding to the satisfaction of Armory mechanics in 1849.[13]

The early American private arms industry was heavily dependent on subsidies and contracts from the national government. Until private firms developed enough technical expertise and non-federal demand to limit this dependence, their standards and methods reflected Ordnance Department requirements. Early Ordnance Department objectives, and the nature of publicly owned factories, were fundamentally different from those of a more mature private arms industry, however. Private firms by the 1840s profited when they could keep costs low while capturing larger markets with new designs.[14] At the national armories, the government was both manufacturer and consumer. Through the nineteenth century, military weapon demands emerged from non-market considerations, and quality generally took precedence over cost. With the Ordnance Department strongly identifying quality with uniformity, new designs and lower costs were secondary considerations in this period. National armory innovations thus had very conservative objectives: greater weapon reliability and factories with reliable facilities capable of expandable output as military needs varied.

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[13] On Springfield achievement of interchangeability, see U.S., Congress, House, Superintendents of National Armories..., pp. 91, 95, 164.

[14] Hounshell, pp. 46-50; Robert A. Howard, "Interchangeable Parts Reexamined: The Private Sector of the American Arms Industry on the Eve of the Civil War;" Donald R. Hoke, "Ingenious Yankees: The Rise of the American System of Manufactures in the Private Sector."

Restricting design changes and emphasizing manufacturing improvements were essential to achieving interchangeability. Although there were few well-established alternatives to the flintlock musket at this time, government arms-makers soon realized that numerous or frequent design changes could jeopardize carefully crafted mechanical arrangements. Army Ordnance small arms goals emphasized production of predictable numbers of weapons with predictable quality, rather than searching constantly for better weapons. Except for the introduction of percussion locks and ammunition, Ordnance Department small arms innovations prior to the Civil War emphasized narrowly focused improvements in manufacturing. Department objectives were conservative, with high value placed on creating an efficient production system requiring as few modifications as possible. As national armory methods improved, standards for small arms quality increased. The Ordnance Department found private arms makers by the 1840s were neither necessary for assuring adequate output, nor generally willing to invest in the increasingly specialized methods needed to satisfy Army requirements.[15] The small size of the United States Army through most of the nineteenth century allowed the Army to make most of its own small arms, other than pistols, from about 1840 to 1917 except during the Civil War.

From 1815 to about 1830, Army small-arms makers concentrated more on weapons quality than on uniformity. Enforcing common standards for arms made at national and private armories was a paramount concern. Interchangeable manufacture remained at best an objective for nearly all arms factories during this period, which can be seen as an important, formative era for later accomplishments. Springfield Armory generally took the lead in meeting Ordnance Department objectives, by creating the technical and managerial basis for large-scale production. Many private arms makers made more significant technical advances, such as the milling devices and gaging systems with which John Hall is credited with first making interchangeable rifles in the mid-1820s as a contractor at Harpers Ferry Armory.[16] It was at Springfield, however, that the small arms industry saw the most systematic efforts to combine available technology with cost controls, plant-wide accounting, and plant-wide work rules. Roswell Lee, Armory superintendent from June 1815 to August 1833, led

[15] Deyrup, pp. 117-32. Until the growth of private and foreign markets for breechloading rifles diminished reliance on U.S. government contracts after 1845, there were important exceptions to the statement about private firms. Burgeoning arms makers such as Remington Arms Company and Robbins, Kendall, & Lawrence made innovative investments to produce the Model 1841 rifle, with some of their technical advances influencing the federal armories.

[16] e.g., Smith, Harpers Ferry, pp. 201-12; E.G. Parkhurst, "Manufacture by the system of interchangeable parts."

these efforts. Advances in mechanization and gaging which resulted in fully interchangeable Armory weapons generally followed Lee's fundamental reorganization.

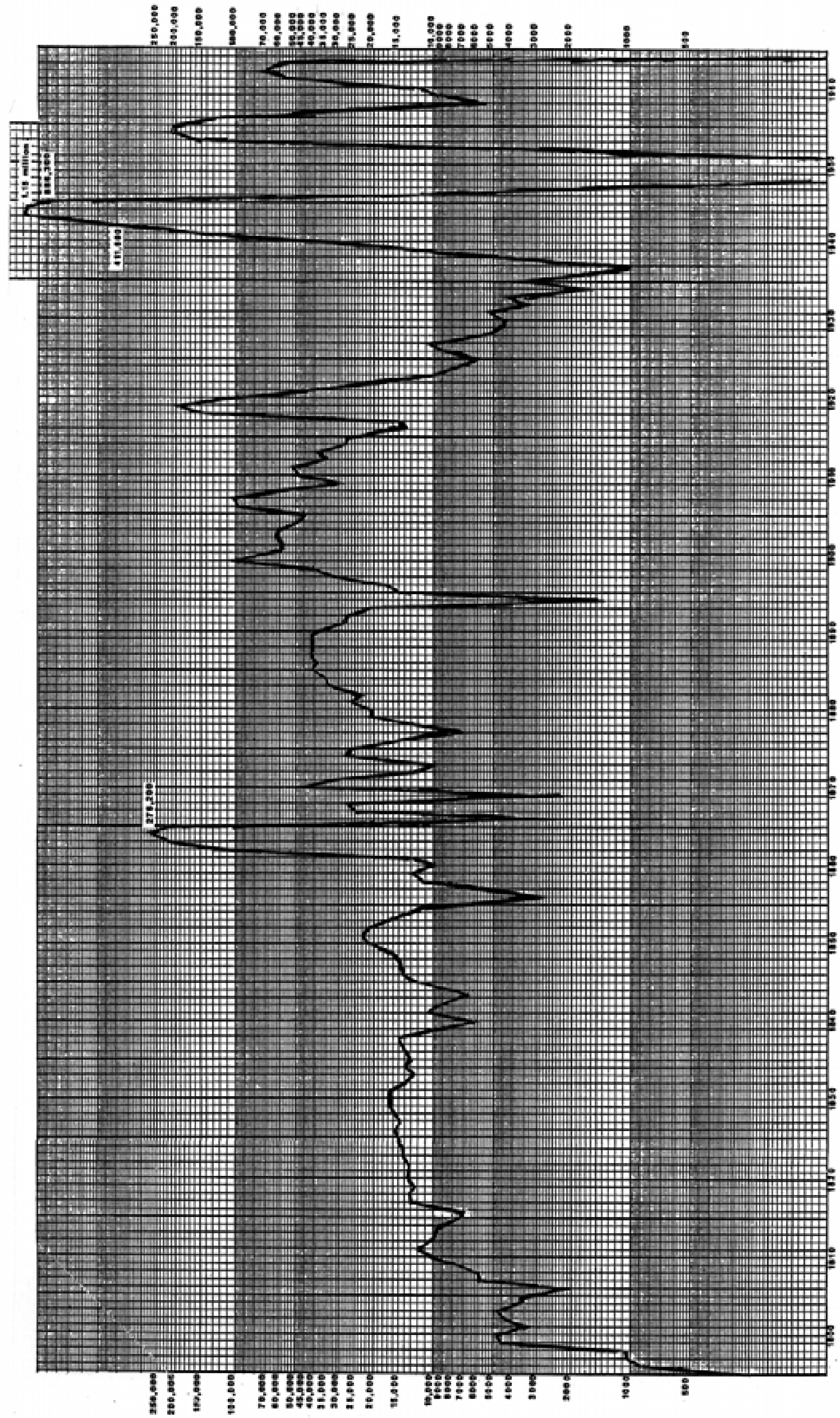

Figure 1.1 SPRINGFIELD ARMORY ANNUAL PRODUCTION OF NEW FIREARMS, 1795–1963. Logarithmic scale; excludes repaired firearms.

Although Armory personnel made few original mechanical developments in this period, Lee oversaw the introduction of significant innovations in mechanizing barrel making and stock-making, in milling some small parts, in controlling the quality and price of critical raw materials and fuels, and in developing gages for inspection of finished arms.[17] These actions addressed the most pressing problems in assuring arms quality and sustained production, but did not make for interchangeable weapons. Lee's responsibilities included selection of private arms contractors, making him a kind of funnel for armsmaking technological development in the Northeast, and what he could not develop at the Armory he borrowed or bought. His most significant procurement of technology was the hiring of Thomas Blanchard, who as a private contractor built a line of water-powered stock-making machinery at the Armory. Blanchard's great achievement of the mid-1820s was the successful development of a fully mechanized production line, unlike anything seen in America at that time. Lee also made important changes in Springfield Armory plant organization and management. He acquired the fourth waterpower site in 1817, which allowed for building a higher dam at the Upper Watershops, and rebuilt or expanded almost the entire plant in response to actual or possible fires (Figure 4.2). He concentrated especially on enlarging storage facilities to control supply costs for coal and iron, and set up a forge to re-use scrap iron at the Lower Watershops. Although he was able to rationalize somewhat the locations of water-powered operations, the Armory's spatial and waterpower limitations restricted any substantial improvements in grouping of operations to minimize transfers of components. Operations were grouped somewhat more discretely than they were before 1815, but spatial arrangements among operations could not duplicate the actual order of tasks.[18] In light of site constraints, however, early 19th century Armory accomplishments were often remarkable (see Chapter 4).

Administrative procedures introduced by Roswell Lee had long-term effects on Armory productivity at least as important as the developments in plant and mechanization, although it took more than four decades for these procedures to mature fully. His greatest administrative problems were a wasteful lack of centralized control over use of materials, and a work force which was irregularly paid, divided by factional disputes, and subject to little regulation. Both these problems grew largely

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[17] Deyrup, pp. 68-100, summarizes Lee's technical and managerial achievements in musket production. We treat these points in more detail throughout this report.

[18] Springfield Armory Work Returns, 1815-30.

from the political structure and divided lines of authority which plagued national armory management, in various forms, until the Civil War. For most of this 67-year period, Armory superintendents were not military or Ordnance Department personnel, but were civilian appointees of the president. Until 1815, lack of unified responsibility for the national armories within the War Department created conflicts between several department agencies, conflicts which often led to factional disputes at the Armory and inhibited the superintendent's ability to control the supply or flow of necessary manufacturing materials. The political origins of the superintendency could give particular virulence to disputes, because Armory workers or their local supporters could contend with a superintendent via congressional channels and indirect influence on the Secretary of War.[19]

The ascension of the Chief of Ordnance to control of national armories in 1815 allowed Roswell Lee, and his counterpart James Stubblefield at Harpers Ferry, to gain control of supply purchases. Lee then addressed the problem of waste and internal supply controls by establishing a firm system of distribution, based on a reorganization of authority over Armory shops and new accounting procedures. Building on Benjamin Prescott's work, Lee set foremen over a half dozen functionally-defined Armory branches, with the foremen receiving materials from the Superintendent's principal aides--the Master Armorer and his assistants--and then assigning materials to workers, with accounts kept of each transfer. This hierarchy improved plant-wide controls of work as well as supplies, since prior to Lee's reforms the master armorer, and one or more assistant master armorers, apparently managed all the shops.[20]

The inherently uncertain footing of a superintendent's power over workers made Lee's success at managing labor more uneven than his reform of supply problems. He proscribed riotous or drunken behavior at the Armory, and established regular shop hours for the first time, requiring 10 hours of work. Although workers valued the stability of government employment, they successfully resisted much control of their behavior outside the shops, and often manipulated both the value of their skills and their political influence to fight wage or force reductions. There problems were particularly thorny for all Armory superintendents between 1815 and 1861, a period when technological changes and limits on superintendent authority created small but periodic upheavals in labor relations. The

[19] Whittlesey focuses on these problems throughout his study.

[20] Roswell Lee to George Bomford, May 12, 1821, RG 156/21; Springfield Armory Work Returns 1815-30.

issue hinged on the high mechanical and manual skills needed by most Armory workers, even as mechanization of operations gradually increased before the Civil War. As we argue in Chapter 6 of this report, there is material as well as documentary evidence that Ordnance Department demands for interchangeability required considerable worker skills throughout the nineteenth century. A scarcity of skilled artificers in an expanding New England industrial economy, including the factories of private arms makers, meant that Roswell Lee had to sustain high wages to keep his labor force intact. At the same time, limits in federal appropriations and Ordnance Department commitments to higher, more mechanized productivity led to periodic assessments of wages and expected output with new production improvements.[21]

Lee dealt with the worker payment issue by giving careful attention to prevailing wages in the region, by creating a health and insurance fund, and by establishing a finely graded system of wages. Rates were based on the quality of work for those paid by the hour, or on the number of components expected from those paid by the piece.[22] Piece rate payment, in effect for at least some tasks from the earliest days at the Armory, allowed for tight controls on output quality when tied to debits made for spoiled or unsatisfactory work. Armory workers favored piece rate payment, largely because it allowed for completion of expected parts in less than expected amounts of time, freeing them for other work outside the Armory. Since Springfield piece rates were calculated by dividing expected daily output of a piece into average daily wage ceilings, this method of payment probably limited any long-term extra earnings incentives.[23]

By 1830, Lee's management and initiative had created a better-organized, more mechanized Armory with a relatively advanced division of labor. Musket output was about 60 percent greater than it was at the start of the War of 1812 (Figure 1.1). The approximately 250 Armory workers produced more muskets than any other such group in the small arms industry, which at that time included the other national armory and seven private contractors working for the Army.[24] Yet achievement of the

[21] Whittlesey; Constance M. Green, "The History of Springfield Armory," vol. I, pp. 27-28.

[22] Green, Vol. I. pp. 30-34.

[23] e.g., James Dalliba, "The Armory at Springfield," Report 246 (1823), American State Papers V, Military Affairs, vol. II, p. 542; Superintendents of National Armories..., pp. 55-6, 64.

[24] Cf. Springfield Armory Work Returns 1815-30 and Deyrup, p. 245.

Ordnance Department's 1815 objectives required additional technical advances and a more consistently cooperative work force, matters which took another three decades to resolve fully. The significance of Roswell Lee's program was that most subsequent Armory management closely followed his format, and achievement of large-scale interchangeable manufacture at Springfield would probably not have been possible without such managerial improvements. Technological advances after 1830 required Lee's systems of accounting, inspection, and shop management for truly effective response to Ordnance Department demands.

The Flowering of Armory Practice, c1830-1861

In the last few years of his superintendency, Roswell Lee collaborated with other Ordnance Department personnel in early development of the first standard issue Army muskets intended for fully interchangeable manufacture. It took the department a decade to design and begin producing these weapons in 1840, although they were not made completely interchangeable until 1849.[25] During the prolonged process of preparing for the new models, Springfield Armory senior mechanics made critical technical advances necessary for large-scale manufacture. Their most important step was the establishment, by about 1835, of a comprehensive practical gaging system for manufacture as well as inspection. They apparently did this by elaboration of existing military small arms gaging systems, such as those used by John Hall and by French makers of a 1777 model musket. The origins of the new system remain obscure, and probably involved exchanges of information with contemporary arms makers such as Hall, Master Armorer Benjamin Moor at Harpers Ferry Armory, and Simeon North at Middletown, Connecticut. Springfield Armory developed the system on a larger scale than any other armsmaking factory at that time, in a manner so successful, for Ordnance Department purposes, that the system of c1835 remained the basis of all gaging systems used for Springfield small arms until after World War I.[26]

During the same period, from the early 1830s to the early 1840s, Armory mechanics -- notably

[25] Several rifle models not made at Springfield, but made by Harpers Ferry Armory, John Hall, and other private contractors, were made interchangeable beginning c1827. Documentary evidence for these achievements is ambiguous, and, as we note in Chapter 3, material evidence suggests considerable hand work was required for the earliest of these rifles. Both annual and total rifle output, made for selected Army units until 1855, was considerably less than that of the standard issue muskets made at Springfield during the same era.

[26] Earl McFarland, "Gaging the Springfield Rifle," pp. 367-8, summarizes the long-term continuity of gage development until World War I. See Chapter 3 of this report for detailed discussion.

Thomas Warner and Cyrus Buckland, Sr. -- concentrated on the development or adaptation of new milling and cutting tools, and filing jigs, which brought musket locks close to dimensional uniformity. Buckland also elaborated on the Blanchard line of stocking machines, becoming perhaps the most important American designer of such equipment. With the exception of an imported British system of barrel rolling introduced in 1859, most of the machines, tools, and skills needed to make large numbers of interchangeable small arms were in place at Springfield by 1845. However, longstanding limits to Armory productive potential frequently constrained output until the Civil War.[27]

Further reorganization of the plant, tighter enforcement of work rules, and stabilization of weapon designs were required before Armory managers could really harvest the fruits of cumulative technical advances. Armory output actually declined during the period when gaging, milling, and stock-making were being improved, not surpassing the 16,500 muskets made under Lee in 1831 until 1850 (Figure 1.1). Army small arms demands remained relatively constant through this period, and three major problems probably account for the downturn in output. First, and earliest, was the administration of John Robb, who followed Lee as superintendent from November 1833 to April 1841. A Jacksonian political appointee, Robb had less success enforcing rules about drinking or work hours, and his superintendency saw a decline in barrel quality along with increased costs for wages and some supplies.[28] The second problem was the limited machine power supply available to the Armory in the Mill River. Finally, there were short-term negative effects of new methods or designs on weapons production. As noted above, new designs could cause substantial disruptions in established manufacturing routines, and the introduction of new musket models in 1840 and 1842 required significant re-tooling episodes, as did the introduction of a new percussion rifle-musket in 1855. Less well-documented aspects of this same problem probably included learning periods required for use of new gaging and milling systems.[29]

[27] Deyrup, pp. 144-60; Charles H. Fitch, "Report on the Manufactures of Interchangeable Mechanism," pp. 1-29; Robert B. Gordon, "English Iron for American Arms: Laboratory Evidence on the Source of Iron Used at the Springfield Armory in 1860."

[28] Whittlesey; Green, Vol. I., p. 68.

[29] Dramatic changes in operations during preparations for new model production appear most readily in Springfield Armory Work Returns 1806-43, and Springfield Armory Payroll Records, RG 156/1379, 1802-98. Model change periods are marked by a virtual disappearance of piece-rate payment, and a decrease in the number of tasks or occupations, while patterns, tooling, and operations for a new model were being established.

Introduction of military discipline and aggressive rationalization of the plant, c1843-59, resolved many aspects of the management and power mechanization problems. Reacting against long-standing management problems at both national armories under Democratic administrations, the Secretary of War for the new Harrison administration substituted Ordnance officers for civilian superintendents in 1841. Congress approved this interim move in 1842. The change to military administration, long desired by Chief of Ordnance George Bomford, allowed for far stricter enforcement of Roswell Lee's work rules. Major James W. Ripley, commanding officer at Springfield from April 1841 to August 1854, removed some armorers and proved particularly resistant to political pressure from dissatisfied workers and suppliers. His administration was marked by bitter disputes with local politicians over land he wanted for Armory expansion, but he took significant steps towards removing the Armory's waterpower limitation through plant expansion.[30]

There had been few changes in the physical plant after Lee's death in 1833. In 1843, as pre-production steps for the new percussion muskets were underway, Ripley started a sustained program of plant expansion to rationalize the spatial arrangement of operations, and to increase output by adding more of the newly designed or modified machines. Armory mechanics built most of the new machines in this period. Ripley added steam power to the Hill shops c1844, which allowed for concentration of all stocking and milling operations in an expanded forge shop at the northeast corner of Armory Square. This part of the Hill, where Ripley oversaw construction of a new machine shop, soon housed a complex of connected structures which housed all metal- and wood-forming operations. Use of steampower enabled Ripley to close the Lower Watershops in 1845, and to move all barrel-making operations to the Middle and Upper water-shop sites. Rebuilding, machinery rearrangement, and dam modifications at these sites evidently allowed for better use of available waterpower, and a more rationalized flow of work and materials. To accommodate greater anticipated production, Ripley built additional Hill facilities beginning in the late 1840s, including the Main Arsenal on the west side of Armory Square, the beginnings of a long storage building north of the square for stocks and lumber, and a large brick cistern east of the storehouse for greater

[30] Whittlesey, chapter 6; Smith, "Army Ordnance," p. 83.

fire protection (Figure 4.3). By 1850, Ripley's building program and stricter rules allowed earlier Armory technical and managerial improvement to operate more efficiently, and musket production topped 20,000 per year for the first time (Figure 1.1).[31]

The era of military rule at the two national armories was interrupted in 1854, after years of attack by local politicians, contractors, disaffected workers, and their Congressional allies. This attack, mounted with a simultaneous attempt by commercial small-arms makers to eliminate federal arms manufacture, resulted in civilian Armory superintendents and temporary cuts in funding.[32] Although production at Springfield declined somewhat as a result, the replacement of Major Ripley by James Whitney did not really slow the improvement of Armory operations. Whitney, who served as Superintendent from October 1854 to March 1860, continued Ripley's firm management but proved to be a far more politic administrator. He succeeded with low-key maneuvers where the major had taken more confrontational approaches, and countered most political attempts to influence his actions or choices of managers. Whitney's most important contribution was the simultaneous rebuilding of the Watershops and the initiation of rifle-musket production. Ripley had considered moving all operations to the Hill in 1852, as did Whitney soon after his arrival, but by early 1855 Whitney decided to combine all waterpowered manufacture at the Upper Water Shops. With the concurrence of the Ordnance Department and the Secretary of War, he spent much of his superintendency building a new, single Water Shops, powered by turbines and handling all barrel-making and most forging operations (Figure 11). The nearly five-year construction program, coupled with the 1856 demolition of the Middle Watershops and the prolonged introduction of the Model 1855 rifle-musket, drastically reduced Springfield Armory output between 1854 and 1858. By 1860, after the rifle-musket was in production and Whitney had added a British barrel rolling mill to the new Water Shops, output was slowly recovering.[33]

Forty-five years of managerial innovation, technological improvements, and plant expansion made Springfield Armory one of the most productive and best-managed factories in the United States on

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[31] Deyrup, p. 233; also see note 5 above.

[32] Superintendents of National Armories...; Green, Vol. I, pp. 88-96; Whittlesey, chapter 6; Smith, Harpers Ferry, pp. 298-308.

[33] Deyrup, p. 233; also see note 5 above.

the eve of the Civil War. The distinctive features of what had become known as Armory practice were well established. These included extensive use of gage controls and powered equipment, 100% inspection of parts, and an elaborate division of skilled, mostly piece rate-paid labor, all combined to make interchangeable, dimensionally uniform products. It was a demanding system, and it evolved with relative indifference to cost. Despite the extensive mechanization in place by 1860, the demands of making interchangeable firearms required considerable worker skills and hand finishing, and continued to do so as Ordnance Department standards were applied to increasingly complex weapons. The required skills, and the relatively constant demands for high-quality output, gave Armory workers much control of actual Armory practice, as well as good pay and employment with some protection from national economic upheavals. Even under military management, these civilian armorers also continued to have recourse to Congressional allies, and to a grading body of federal laws governing public employment, in any disputes with Armory commandants. Military rule of the Armory thus rarely involved shop controls tighter than those seen in private plants, but did allow for somewhat stricter enforcement of work rules than was possible under the more politically sensitive civilian superintendency. The unusual combination of required skills, high-quality products not susceptible to market forces, and public employment made Springfield armorers a crucial link in Army weapons procurement, a link not readily re-forged or hammered. This situation helps explain why there were few significant labor disputes in Armory history, and why many employees worked at the Armory for decades. Unlike their counterparts at Harpers Ferry who felt threatened by some technological changes, Springfield armorers generally seem to have understood that these changes made them more important, not less so.[34]

Springfield Armory in 1860 was much better at making rifles than it was at designing them. The conservative goals of Ordnance Department small-arms making, and the difficulties inherent in changing the carefully wrought system of Armory practice, affected approaches to research and new weapons designs. Springfield Armory played an important, though by no means paramount, role in antebellum weapons tests. Department officers and mechanics became adept at weapons testing, and actively studied new domestic and foreign designs. They also became extremely cautious about using new designs until they knew the designs could be manufactured to department standards of uniformity, with maximum use of existing methods, or until they knew that other major military

[34] Smith, Harpers Ferry, pp. 323-35; see note 17 above.

powers were using the designs. These biases, and limited government support for research, severely restricted any formal development of research in small arms design. Until the late 1840s, this approach had few apparent flaws since available good designs were limited. But just as Springfield Armory was perfecting it methods and improving its plant, private arms makers and inventors, adapting some Armory methods, began to expand the universe of shoulder arms. By the Civil War, the commitment to Armory practice left the Ordnance Department poorly adapted to initiate or develop any major design changes requiring radical alterations in method.[35] Springfield production capabilities became crucial in this crisis, however.

From the Civil War to the Magazine Rifle, 1861-1893

The timing of Springfield Armory's successful development of a large scale musket-making system was fortuitous, but proved extremely fortunate for the Ordnance Department. The department was unprepared for the Civil War, and in fact had abetted Secessionist plans by transferring arms, equipment, and practical knowledge to Southern armories at the insistence of secretaries of war (and later prominent Confederates) Jefferson Davis and John B. Floyd.[36] Harpers Ferry Armory was destroyed early in the war, and Springfield was not operating at fullest capacity when the conflict began. To meet large immediate demands for small arms, the Ordnance Department soon turned to domestic contractors and foreign suppliers. The latter sent about 726,000 shoulder arms of numerous types during the first fifteen months of war, but from that time forward the Armory and the contractors made such purchases unnecessary.[37]

Former Armory commandant James Ripley became Chief of Ordnance in April 1861, and immediately re-instated military command over the Armory. The new commandant, Capt. Alexander Dyer, had firm wartime control, including an oath of allegiance required by Congress, over the large number of new workers.[38] Armory production skyrocketed under Dyer, who

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[35] Registers of Ordnance Department correspondence relating to experiments, inventions, and improvements provide vivid impressions of the pace, timing, and nature of private designs, in RG 156/192, 193, and 199; also, see note 17 above.

[36] Whittlesey, chapter 7.

[37] Weigley, p. 203.

[38] Whittlesey, chapter 7.

commanded at Springfield from August 1861 until his appointment as Chief of Ordnance in October 1864. He added a second work shift, and, with the help of civilian managers, sifted the existing division of labor more finely. In contrast to the antebellum workforce, few of the wartime armorers performed more than one narrowly-defined task. Expanding on the Armory's late antebellum methods, Dyer oversaw a ten-fold increase in the workforce to, at times, more than 2800 men. In 1864, these men made more than 276,000 rifle-muskets. With relatively modest expansion in plant, they made over 800,000 rifle-muskets during the war, or about 11% more muskets than the Armory made during the preceding 66 years of its operation (Figure 1.1). This output represented more than one quarter of all shoulder arms made or procured for the Army in the war, and about 54% of all rifle-muskets made to standard issue patterns. The Armory out-produced more than thirty private contractors making the Army rifle-musket, while providing them with gages, inspectors, and models.[39]

For the first time, the Armory purchased a large number of new milling machines, but continued to make some machines and most jigs and fixtures. Dyer used the new equipment with an expansion program longer on spatial rearrangement than new construction. At the Hill shops, new construction included additional machine shop and machine forging space at the already crowded northeast corner of the Armory Square quadrangle, a large addition to the lumber and stock blank storehouse north of the quadrangle, and temporary facilities (probably for storage) east of the quadrangle in what would later become Federal Square. Dyer added new or larger steam engines to the machine shop complex, and to the middle of the three older arsenals on the south side of the quadrangle. All three of these arsenals were converted to production purposes, allowing for removal of the stocking line from the machine shops, which now housed part of a greatly enlarged milling department. Some milling operations were moved to the adjacent east side of the quadrangle, where Dyer combined and enlarged three separate structures formerly used for filing, finishing, and offices (Figure 1). With conversion of the three arsenals for finishing of rifled barrels, stocking and rifling, and final assembly, the Hill Shops for the first time had a functional and spatial division of tasks which closely matched the order of production. At the recently-finished Water Shops, only small additions were required during the war, although Dyer added steam power to these shops for the first time to

[39] Robert M. Reilly, United States Military Small Arms 1816-1865, pp. 72-5; Weigley, pp. 235-8; Green, Vol. I, pp. 114-33; wartime division of labor changes appear clearly in multi-decade comparisons of data from Springfield Armory Work Returns and Payroll Records (notes 7 and 28 above).

overcome any waterpower deficiencies.[40]

Chief of Ordnance Ripley helped assure greater Armory production by resisting attempts to introduce breech-loading rifles into the Army for any non-cavalry units. His own experience directing the early production of the Model 1842 musket at Springfield probably fueled his skepticism about wartime model changes.[41] The performance and availability of patented breechloaders during the war made their introduction inevitable, however, and several unit commanders supplemented the government purchase of almost 400,000 such weapons with private or state procurement.[42]

The Ordnance Department began a prolonged search for a new service weapon after Dyer took command in 1864. In the absence of other national armories, Springfield for the first time took the lead role in this process, which evolved into a generation-long episode and established the Armory as the center of military small arms research within the government. The post-Civil War Army had greatly reduced manpower and funding, a fact which contributed to a relative lack of innovation in small arms design or production methods at Springfield Armory from 1865 to the early 1890s. Under Maj. James Benton, commanding officer from June 1866 until his death in August 1881, there was significant expansion and development of ballistics research facilities, and the beginnings of a permanent research facility in an experimental firing house built in Federal Square. This new research capability did not, however, encourage Armory personnel to make or recommend any dramatic model design changes. Armory officers and mechanics developed breech-loading and magazine rifle designs with minimal differences from the rifle-musket, despite the commercial availability of designs which were more reliable. Reluctance to tamper with the production system which helped win the Civil War, probably aggravated by limited funding and long-standing suspicion of non-military designs, accounted for much of this bias. After the Army adopted a series

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[40] See note 5 above.

[41] Ripley's decision was warranted by performance as well as production issues. Although breechloaders could fire faster than rifle-muskets, the Army issue weapon had greater range, power, and accuracy. Many breechloaders were also subject to problems not solved until the war ended, such as gas leakage at the breech and a lack of high quality, mass-produced metallic cartridges. Other considerations, such as resistance to paying royalties on patented designs and fear of uncontrolled firing by troops, affected Ripley's decision as well, but his stance was not the technologically backward one sometimes perceived by Civil War historians. See Carl L. Davis, Arming the Union: Small Arms in the Civil War.

[42] Huston, p. 186.

of Springfield-designed breechloaders, culminating in the Model 1873, only the growing acceptance of magazine rifles by foreign armies made selection of a similar weapon a priority for the United States. Armory conservatism contributed to the final selection by an Army board of a Norwegian magazine rifle design based on one used by the Danish army: no acceptable American design had appeared in or out of the military. Final Congressional approval of the Krag-Jorgensen rifle in 1893 created a new set of challenges for the Armory, now charged with the manufacture of a rifle radically different from anything made before at Springfield.[43]

By 1893, antebellum Armory practice had developed considerable inertia. With the exception of a few technical changes such as the adoption of profiling machines during the Civil War, the use of steel rifle barrels beginning c1873, and limited use of multiple fixtures on milling machines in the 1880s, the Armory in 1890 operated in much the same way as it had in 1860. The end of the war, and the dramatic drop in the demand for Armory products and workers, led to something like pre-war plant arrangements. The three arsenals on the south side of Armory square were demobilized. Much of the machinery amassed during the war went into storage.[44]

Congress and the Army realized by the mid-1880s that production of a magazine rifle would eventually be necessary. Under Lt. Col. A.R. Buffington (commandant October 1881-February 1892), the Armory began construction of a completely new rifle plant in 1888. Displacing the Federal Square firing house, three iron-framed brick shops for milling, machine and filing work, and stocking and carpentry arose to form a square with Federal Street (Figure 4.5). The new complex, nearly complete by 1893, provided more fire resistance and a somewhat more compact manufacturing arrangement than the Armory Square shops, which became largely devoted to storage. In the absence of a new rifle model, however, plant construction proceeded slowly, and the complex was not set up for production until after the selection of the Krag rifle.[45]

The post-war Armory work force fluctuated between about 250 and 500 men. Except during periods

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[43] ARCO 1870-93; see notes 5 and 17 above.

[44] SFSA 1865-90; U.S., Congress, Senate, ...the cost of manufactures at the National Armory...; Springfield Armory Payroll Records, 1860-90; U.S., Ordnance Department, The Fabrication of Small Arms for the United States Service.

[45] See note 5 above.

of breechloader model changes, or Congressional funding cuts, these men usually turned out 20,000-40,000 new weapons a year (Figure 1.1). Armory output, often twice what it had been in the late antebellum period with a work force of comparable size, attests to the maturity and productivity of traditional Armory practice.[46] Any signs of the occasional disputes over hours or work rules, which punctuated Armory life from Roswell Lee's time until the mid-1850s, disappeared in a period of steady, rather undemanding employment at relatively high wages. Military control of the Armory remained permanent after 1861, and increased with the assignment of subordinate officers beginning late in the Civil War, but apparently created little problem for the highly skilled civilian workforce. Many of these men stayed at the Armory for decades, creating an important reservoir of skill which was not again tested until the Army demanded the new rifle.

Magazine Rifle Challenges to Armory Practice, 1893-1918

Despite the new plant, lack of Armory involvement in preparation of the final new rifle design was unprecedented, and left the senior mechanics and armorers unprepared for Krag production. The Krag's breech mechanism and barrel steel requirements differed significantly from those of earlier models. Operations came to a standstill while Armory staff worked out new forging patterns, milling operations, gages, metallurgical standards, and barrel-making procedures. Col. Alfred Mordecai,[47] commanding the Armory from February 1892 to February 1898, was under great pressure from the Chief of Ordnance to produce the new rifle. He successfully directed Krag production through numerous design and manufacturing changes, a process which involved often painful reorganizations of the labor force. Often impatient with traditional practice in the face of radically different production problems, he sometimes failed to recognize that the shop skills needed for such practice were the same skills he would need to adapt the new design to the Ordnance Department's rigid standards.[48]

Mordecai tried to minimize hand finishing by more precise milling, and to increase output with

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[46] Springfield Armory Payroll Records, 1865-92; SFSA 1865-92.

[47] Mordecai (1840-1920) served in the Army from 1861 to 1904. He should not be confused with his father, also Alfred Mordecai (1804-87), and also a prominent ordnance officer 1832-61. See Who Was Who in American History - The Military.

[48] See chapters 6 and 7 of this report.

more multiple milling fixtures. In the most powerful exercise of military authority at the Armory since the days of James Ripley, Mordecai removed a number of older workers he felt were unable or unwilling to meet new production requirements. For many remaining workers, there was same additional upheaval in the need to revise completely the piece rates which dominated Armory wage reckoning. Mordecai also replaced several shop foremen with younger men, and increased both their shop responsibilities and their accountability to him. Traditionally, the master armorer had been the commanding officer's principal assistant, and took primary responsibility for modifications in machines, tooling, and fixtures. When Master Armorer S.W. Porter died in June 1894, Mordecai and his superiors decided not to fill the position, and the foremen took over most of the Master Armorer's responsibilities in their respective shops. About the same time, Mordecai assigned his small contingent of subordinate officers to take charge of groups of shops. Some of these officers oversaw three or more separate shops. Although they had neither the expertise nor the time to manage daily production, they added a degree of constant, military regulation of specific shops.[49]

In addition to problems with smaller rifle components, acquiring appropriate barrel steel proved to be exceedingly difficult. The Armory had little experience with metallurgical testing, and its officers had to use expertise from Watertown Arsenal and private steelmakers in steel selection until the problem was resolved c1900. The barrel steel issue gradually pushed the Armory into acquiring equipment for materials testing and temperature control, adding another arm of informal research to existing, separate facilities used to test new small arms designs. Armory research efforts remained relatively informal and fragmented until World War I, and apparently lacked permanent staffing until that time. A small Experimental Department, established in the early 1890s, consisted largely of testing facilities used for evaluating new small arms designs when Armory officers were not managing the rifle plant.[50]

Col. Mordecai pursued large-scale production of the Krag through his entire tour of Armory duty. After making two model changes, incorporating numerous alterations for better operation and easier manufacture, the Armory by the eve of the Spanish-American War was making 30,000-40,000 rifles annually--output similar to figures for trapdoor breechloaders ten years earlier. Despite Mordecai's

[49] Ibid.; Springfield Armory Post Orders 1890-98; ARCO 1893-1900.

[50] ARCO 1892-1900.

claims of decreased handwork and more precise milling, the nearly 600-man workforce's annual rifle output per worker showed little increase. Manufacture of the Krag and Model 1903 magazine rifles at Springfield Armory involved extremely innovative use of jigs and fixtures, ganged cutters, and a mix of old and new machinery. In terms of rifle output per worker, however, traditional Armory standards for uniformity limited the effects of these improvements.[51]

The magazine rifles were far more complex and difficult to make than earlier Springfield weapons, requiring more operations and increasingly elaborate gaging systems. Applying traditional uniformity standards, which at least in theory had few explicit tolerances, essentially required the Armory to work harder at maintaining acceptable productivity. Uneven funding for new machinery hampered these efforts somewhat, but was probably less decisive a factor than the focus on manufacturing method rather than manufacturing objective. Emphasis on dimensional uniformity, rather than functional interchangeability with acknowledged tolerances, remained a significant problem for Armory productivity through the magazine rifle era (see chapter 3). The fact that Armory inspectors recognized acceptable tolerances, employing an unwritten set of rules carried "under their hats," did not allow for potential emergency expansion of operations with new personne1.[52]

The Spanish-American War of 1898 provided the first hint that Armory innovation directed at conservative production standards could have serious implications for military procurement. Although the small Regular Army was fully supplied with Krag rifles in 1895, Armory output was not sufficient to arm the volunteer regiments. During the war, Springfield quickly tripled its work force to about 1800 men, put on a second shift, brought in additional equipment, and set up shops in Federal Square basements. The shortness of the war did not allow for enough production to remedy the problem for the volunteers, who sometimes found themselves at a disadvantage using black-powder cartridges and trapdoor rifles against Spanish troops armed with Mauser magazine rifles with smokeless powder cartridges. Many field officers also noted the greater power of the Mauser relative to the Krag. These and other supply problems ended the century for the Army on a distinctly

[51] Ibid; Springfield Armory Payroll Records, 1893-1898.

[52] McFarland, p. 368.

unhappy note, and led to significant reorganization.[53]

Ordnance Department response to these problems included construction of a second rifle plant at Rock Island Arsenal in Illinois, expansion of facilities at Springfield, and complete Armory redesign of the magazine rifle to incorporate Mauser advantages. At Springfield, the Water Shops were partially rebuilt and expanded from 1900 to 1902, with a new front shop extending over the Mill River (Figure 4.6). New boilers, furnaces, and DC motors installed by 1903 increased Water Shops efficiency, especially when running rebuilt line shafting systems with separate, motor-driven sections.[54] The new Model 1903 rifle, modified until 1906, was sufficiently similar to the Krag that the transition in production was the smoothest in Armory history. Absence of prolonged re-tooling did not rectify the fundamental problems of balancing increasingly complex designs against uniformity standards made for earlier and simpler weapons, however. The Rock Island rifle plant remained a relatively low-volume auxiliary to Springfield throughout its irregular 1905-18 production history.

Armory managers renewed efforts to improve productivity after 1906, emphasizing managerial and plant changes as well as mechanized production methods. Some of these changes followed from Chief of Ordnance Brig. Gen. William Crozier's prolonged attempts to introduce scientific management systems into his department between 1906 and 1915. With industrial productivity receiving national attention through the efforts of Frederick Taylor and others, Crozier sought favorable comparisons with private industry in his Congressional relations. Strikes at the Watertown and Rock Island arsenals limited the use of time studies and piece rates in the department, but at Springfield a century's development of piece rates precluded the need for such studies or conflict. New Armory practices borrowed or influenced by Taylorism included centralized planning for better routing of tasks and components, improved accounting systems for tools and raw materials, introduction of high-speed tool steels, and reorganization of shop floors.[55] By 1915, Armory managers also obtained substantial amounts of new equipment and completed direct rail links from

[53] Weigley, pp. 285-318.

[54] See note 5 above.

[55] ARCO 1906-1915; ARSA 1906-1915, SANHS; Hugh G.J. Aitken, Scientific Management in Action: Taylorism at Watertown Arsenal, 1908-1915.

the Armory to trunk lines and from the Hill to the Water shops. Better on-site transportation, along with increased use of electrical power and rebuilt power transmission systems, removed most of the Armory's long-standing geographic and power supply limitations.[56]

Capital improvements, and new accounting practices to control manufacturing materials purchases, had significant effects in reducing production costs, but still left the Army with a limited capacity to respond to a major conflict. In the year ending June 1910, before Army rifle demands were fully met, about 900 Armory workers made about 47,000 small arms, representing if anything a decline in rifles made per worker over previous decades (Figure 1.1).[57] The Model 1903 rifle, probably the most precisely manufactured weapon ever made at Springfield Armory, was difficult to make quickly given the large number of operations and the level of uniformity required. The Ordnance Department's reluctance to contract for rifles, and the disparity between federal and private manufacturing methods highlighted by often obsessive uniformity standards at Springfield, made it difficult to plan for any industrial mobilization.[58]

With little attention to wartime mobilization, and the Regular Army supplied with new small arms plus a reserve of about 600,000 rifles, Congressional funding for the armories actually declined after 1912 until just shortly before American entry into World War I. Lack of preparation generally marred Ordnance Department efforts in that war, and led to major departmental reorganization. Rifle supplies proved adequate for the wartime Army, but only because the Winchester and Remington companies were contracted to make a new version of the Enfield rifle, originally made for the British. Modified by small arms developer John T. Thompson, a former Ordnance Department officer returned to wartime service, the privately-produced Model 1917 rifle was chambered for 1906 .30” cal. American cartridges, and made only partially interchangeable in a manner more suited to commercial manufacture. At three plants, the private arms makers made nearly seven times as many M1917s as the two federal plants at Springfield and Rock Island made M1903s. In New Haven, Connecticut, the Winchester plant made about 465,000 M1917s, but Springfield

[56] See note 5 above.

[57] ARSA 1910.

[58] ARCO 1895-1907; Aitken; Daniel R. Beaver, "The Problem of American Military Supply, 1890-1920."

Armory made only some 270,000 M1903s during the war months.[59]

Armory improvements made prior to the war, the decision to use the Model 1917, and the relatively brief period of hostilities precluded the need for any extensive new wartime construction. A number of temporary frame structures met additional storage and handling demands, and a small brick addition to the Federal Square milling shop provided increased space for inspection of rifle components (Figure 4.7).[60] The most important new facilities were for testing and quality control. New staff and equipment in a brick metallurgical and chemical laboratory, appended to the machine shop complex in Federal Square, tested the quality of all steel arriving at the Armory for components, gages, and tools.[61] Although these plant additions rectified some production problems, they could not overcome more basic obstacles to productivity which contrasted Armory performance so markedly with that of Winchester and Remington.

Two-shift wartime production at Springfield, with more than 5000 workers by the Armistice, was hampered by three principal, closely-related problems. The first, never openly admitted by Armory managers, was the inherent limitation of traditional Armory practice in making magazine rifles. A 1917 contract with Greenfield Tap & Die Company, to design gages reflecting tolerances of as-built M1903s, was the first implicit recognition of this problem, and the earliest instance of Armory contracting for gages. Wartime production demands delayed use of the new gages until after the war. A second problem was a relative shortage of newer, higher-speed equipment, despite the exercise of considerable skill in utilizing older types of machines. Pre-war funding limitations accounted for much of this shortage. Securing enough skilled workers was the third problem. Increased mechanization and decreased handwork had never meant extensive "de-skilling" at Springfield. On the contrary, not only was some hand fitting necessary until World War II, but many machine operations required more skill when components were taken closer to gage. High wartime employment, and American contracts for European armies, created difficulties in retaining skilled workers at the Armory. Traditional worker training at the Armory, on shop floors, proved

[59] Weigley, pp. 348-64; Beaver; Norm Flayderman, Flayderman's Guide to Antique American Firearms, p. 481; ARSA 1917-19.

[60] See note 5 above.

[61] ARCO 1918, pp. 1059-60.

inadequate for the much larger wartime force, as did a limited course of instruction. Armory managers turned to women for the first time in this crisis. By the Armistice, women comprised about 16% of the workforce, employed principally in filing, inspecting, and packing, with a small number also doing machine work.[62]

Preparing for another War, 1919-1941

The end of World War I gave Springfield Armory an opportunity to upgrade its magazine rifle capabilities. With newer, government-owned equipment transferred to the Armory from government contractors, increased shop electrification, and gradual introduction of the new Greenfield Tap & Die gages, the Armory was fully prepared to re-fight World War I by 1924. Drastic cuts in military funding from 1921 to 1935 put production facilities on reduced standby status, however, used largely for rifle and pistol repairs, and for production of small arms components. All production lines were consolidated at the Water Shops. Much of this activity represented minimal levels needed to retain a core of skilled personnel. Civilian and military staff reduction, and frequent reassignment of commanding and subordinate officers, meant that continuity of armsmaking expertise rested largely on senior civilian staff. Workforce size returned to levels of the 1880s, and actual arms output fell to levels of the early 19th century in the absence of military demand (Figure 1.1).[63]

For the first time in its history, Springfield Armory's most important work became development, rather than production, of small arms. The Armory had been the de facto center of Ordnance Department small arms testing since the Civil War, but had done very limited work developing new arms designs. Virtually all design changes suggested or implemented by Armory personnel before 1919 were modifications of existing models, modifications minimized changes to limit disturbance of production methods. The Ordnance Department did not specify design problems and solicit potential private solutions, but instead evaluated available models of general classes of weapons, such as magazine rifles. From the beginning of the twentieth century, it was clear that semi-automatic, or self-loading, weapons would prove increasingly important. Semiautomatic pistols appeared quickly, and by 1911 the Armory helped select a Colt model for Army use.[64] Rifle designs

[62] ARSA 1917-19; see chapters 6 and 7 of this report.

[63] ARSA 1919-35, SANHS; Green, Vol. II, Books I-II.

[64] ARCO 1911, 1912; Flayderman, p. 108.

acceptable to the Ordnance Department proved more difficult to develop.

Beginning in 1901, the Armory's Experimental Department had either tested semi-automatic rifle models submitted by private inventors, or had modified Springfield weapons, with little success. World War I made the slow pace of this work unacceptable to the Army: no infantry officer could now ignore the need for greater offensive power against machine guns, and other industrial powers were trying to develop semi-automatic rifles.[65] The war also discredited reliance on the random achievements of inventors as a viable research strategy for any Ordnance planning.[66] Changing its established methods, the Armory put several Ordnance officers and two civilian inventors at work full time on completely new rifle designs. In the only significant early post-war expansion of Armory facilities, commanding officer Lt. Col. Lindley Hubbell directed the completion of new Experimental Department testing facilities north of Armory Square, and the establishment of a separate Model Shop for new design work at the north end of the Administration Building (Figure 4.7).[67]

Civilian employee John Garand, who arrived at the Armory in 1919 to participate in new rifle design work, produced a new rifle design which the Army accepted in 1936. The development period was prolonged by post-war changes in Ordnance Department control over new designs, and by concerns over any use of new cartridges which would 'waste' the vast accumulated supply of .30” cal. 1906 ammunition available for rifles and machine guns. In the wake of the department's generally mediocre performance during World War I, line officers for the first time gained a significant voice in design decisions, and through an Ordnance Committee requested sometimes contradictory changes and performance objectives. Garand's genius, and his ability to create alternative designs quickly, was more responsible for the semi-automatic M1 rifle than the

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[65] For automatic rifle development, the most useful sources are Melvin M. Johnson, Jr. and Charles T. Haven, Automatic Arms; Philip Sharpe, The Rifle in America; and Edward C. Ezell, The Great Rifle Controversy. John Ellis, The Social History of the Machine Gun, summarizes the tactical effects of automatic weapons on infantry planning. On early Springfield Armory research on semi-automatic rifles, see William H. Davis, "U.S. Rifle Caliber .30, Ml."

[66] Hunter Dupree, Science in the Federal Government, pp. 301-25.

[67] ARSA 1919-20.

organization of Army small arms research.[68]

The acceptance of Garand's rifle design in 1936 proved to be extremely fortunate for the Army. Accelerated war planning, under Gen. Malin Craig (Chief of Staff, 1935-39), de-emphasized research in favor of rapid production of the best available weapons. Increased military funding in this period thus allowed Springfield Armory to prepare for M1 production without sacrificing any design features.[69] Following several years of equipment purchase, production engineering, and rearrangement of departments, the Armory in 1939 began building or enlarging structures to make the new rifle. By mid-1941, both Hill and Water shop areas had important new brick facilities. On the Hill, a large new milling shop east of the older Federal Square structures was set up for all M1 components except barrels and stocks, while a smaller structure east of the 1890s machine shop accommodated all filing, polishing, and heat treating. The East Arsenal in Armory Square was enlarged for storage space. At the Water Shops, new structures south of the pond held the M1 clip line and facilities to test fire machine gun barrels. Barrel manufacture was upgraded with new forge hammers, and heat treating and forging equipment installed in a large, rebuilt World War I target house southwest of the Water Shops (Figures 4.8, 4.9).[70]

The M1 pre-production process was complicated by the new rifle's significant differences with the M1903, and by the need to build a much larger skilled workforce. Anticipating the former problems during the long design period after 1919, Armory managers slowly began to replace older manufacturing equipment in 1930. In this process, they bought equipment already supplied with tools, jigs, and fixtures when possible, reversing traditional Armory practice and adapting available commercial technology to new rifle design. Motor drives replaced belts on many new and some old machines, completing a move away from line shafting which began right after World War I.[71]

Greater reliance on available commercial technology not only facilitated acquisition and use of new

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[68] Ezell, Controversy, pp. 20-35; Julian S. Hatcher, The Book of the Garand, pp. 28-34.

[69] Weigley, pp. 404-8; Constance M. Green, Harry C. Thomson, and Peter C. Roots, The Ordnance Department: Planning Munitions for War, pp. 32-7, 47-54.

[70] See note 5 above.

[71] ARSA 1935-41, SANHS.

equipment, but allowed for easier training of new workers with any prior experience in machine tool use. As with World War I, however, finding and keeping large numbers of new workers initially proved difficult for the Armory. Improving economic conditions in the Springfield region created a tightening labor market just as Armory preparations for M1 production quickened. Armory management again met this problem with higher wages, with greatly expanded shop-floor training of new workers, and with increasing employment of women. Initially hesitant response to new wage demands, and the increasing presence of officers on shop floors after 1935, created sporadic worker-management disagreements which resulted in a new labor union. The new lodge of the American Federation of Government Employees, established in 1937, was instrumental in initiating a general Armory wage survey. Although Armory management was more well-intentioned than effective in its industrial relations, wage levels at least equal to those in comparable local jobs kept applicants coming and union grievances to a minimum.[72]

By mid-1941, the civilian workforce had quintupled from levels five years earlier, with more than 4900 men and women, rising to about 7500 on the eve of Pearl Harbor. The joint management of shops by Ordnance officers and civilian foremen remained a point of resentment for many newer workers, unused to military controls and unaware that the practice dated to the late 19th century: it appeared to be a new development only because the drastic 1920s staff reductions had removed most officers from the Armory. Officers in the shops were an occasional flashpoint for worker protests through World War II.[73]

The Ordnance Department spent over three years actively planning for World War II, and, in contrast to its World War I performance, was well-prepared for unprecedented logistical demands. A key element in this planning was early involvement of private firms for industrial mobilization, using "educational orders" to prepare firms for department requirements. World War I ordnance supply problems had made the folly of wartime Army reliance on public factories clear. The increased importance of buying armament from private firms was probably the most important change in Army Ordnance procurement after the War of 1812, with profound effects after World War II. Springfield Armory was first touched in 1939 by what would become a basic change in its

[72] Green, Vol. AI, Book II, pp. 67-9, 108-16, 121-2, 127-8.

[73] Ibid, pp. 67, 87, 108-11.

mission, when Winchester received an order to make M1 rifles. This order marked the first time since the Civil War that a private armory made the standard infantry rifle. The Armory also leased older machine tools to private firms with other armament orders, while it concentrated most of its efforts on M1 production.[74] Wartime Armory exertion proved to be extraordinarily successful for production purposes, but poorly suited to a new order of procurement practices.

A Failed Transition: From Production to Development Missions, 1941-1968

Seven years of preparation gave the Armory a tremendous head start in making M1s for the wartime Army and Marines. Few new structures were built after Pearl Harbor, with the last finished by mid-1942. These included a brick gunstock and machine shop southeast of Federal Square, and storage and field service buildings north and east of Armory Square.[75] During the war years, the Armory delivered over 3.1 million rifles, more than six times as many as Winchester, the only other maker of M1s, made in New Haven (Figure 1.1). Although the private plant also made more than 800,000 M1 carbines, with a design rapidly developed by the firm for the Ordnance Department, Springfield's performance was a dramatic reversal of the small arms situation in World War I.[76] Continual improvements in production practice and increased worker output were the key elements in the Armory's success. Greater use of broaching, and extensive conveyor networks in the new milling shop, were among a large number of modifications which kept research staff and production engineers constantly occupied.

Wartime civilian employment ranged between about 7,500 and 13,500. Women played an increasingly important role, comprising 43% of the workforce by mid-1943 and dominating some production lines such as stock-making.[77] Annual output per worker at times exceeded 90 rifles. This was the highest such rate achieved at the Armory after the Civil War, when the comparable output figure may have exceeded 100. The M1 was a vastly more complex machine to make than the rifle-musket. World War II productivity levels were achieved in part through extensive use of faster

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[74] Weigley, pp. 408, 431-5; Green et al., pp. 31, 36, 41, 59; Green, "Springfield Armory," Vol. II, Book II, pp. 85-6, 93, 131.

[75] See note 5 above.

[76] Davis; Harold F. Williamson, Winchester, the Gun That Won the West.

[77] Green, "Springfield Armory," Vol. IA, Book III, pp. 147-151.

equipment and streamlined handling of components, but reversals of traditional features of Armory practice were perhaps even more important. During the period of greatest demand for M1s, which lasted into early 1944, strict conformity of finished work to gage often lapsed with little discernable effect on rifle quality.[78] Whether by accident or design, John Garand's rifle reversed the historical trend of Army rifles with increasing complexity and decreasing manufacturing and operational tolerances. At this time, the M1 was the most intricately designed rifle made at the Armory, but it usually functioned well with a wider range of finished tolerances than the less complex but more precisely made M1903. Thus a temporary decline in Armory inspection standards actually helped boost acceptable output.

During the war, Springfield Armory made only M1s and barrels for .50” cal. machine guns. Armory technical responsibilities in this period were far broader, however, including issuing specifications for design, manufacture, and inspection of virtually all small arms procured by the Army. The Ordnance Department relied on private industry for most of these weapons, and gradually insisted on increasing conformity between private and Armory practice in management and inspection procedures. This new department demand began to transform traditional Armory methods as M1 demand declined. Armory officers reorganized inspection practices in 1944 after the extent of the non-conformity of parts to gage became apparent. They evidently did so because they felt that traditional standards and practices should be maintained, and because private contractors needed standards and models for their own ordnance work. The revised inspection system included in-progress checks at each machine on the shop floors, and a new card control system, both of which components were developed after Armory personnel observed process control systems at several Midwestern plants.[79] The Armory had for decades been adapting commercial machinery and even gaging systems to its own purposes, but this episode marked perhaps the earliest instance of molding Armory inspection methods to commercial procedures.

New procurement realities, which developed very quickly before the end of the war, would henceforth limit the Armory's ability to control the direction or nature of its mission. Virtually everything done at the Armory after the war had to account for potential or actual commercial

[78] Ibid., pp. 473-77.

[79] Ibid; Anonymous, "History of the Springfield Armory," Vol. II, Book III, pp. 763-8.

production of Army small arms. Commercial management practices had tremendous impacts on wartime planning and procurement, forcing the military to meet similar standards of efficacy. Worldwide American military commitments also required a constant state of industrial planning for mobilization or enlarged peacetime forces. Given the nature of greater military demands, and the proven ability of private industry to supply wartime needs, military and political leaders did not intend to expand the public arsenals to meet all future ordnance requirements. Extensive reliance on military factories for production was over.

By World War II, Springfield Armory had developed two great strengths. It had the potential to produce very large numbers of weapons, and it had the capability to test, engineer, and manufacture a wide variety of small arms. Armory managers deliberately sacrificed some of the latter strength during the war to concentrate on M1 production. With the decline of demand for M1s, as well as for other small arms made commercially with Springfield technical assistance, the Armory found itself in search of a mission: its principal product was no longer so urgently needed, and future weapons demands would be met at least in part through commercial contracts. As the war was ending, Armory managers began explicit planning for a revised mission. Their strategy was to capitalize on the Armory's technical responsibility for national small arms procurement, by stressing their second strength--the breadth of small arms expertise--and emphasizing the fresh success of the M1 development program. By 1947, they had secured responsibility for small arms research and development, design and product engineering, technical oversight of all Army small arms procurement, planning for small arms industrial mobilization, and pilot line production for aid to contractors and quality control. Although Armory employment fell rapidly when Germany and Japan surrendered, to between two and four thousand people for most of the period prior to the Korean War, Springfield's future seemed secure in a new role.[80]

To maintain a need for Armory skills in the post-war procurement climate, Springfield had to succeed in two different, but related, tasks. First, it had to meet military demands for new small arms designs through its expanded research and development sections. Second, it had to translate new designs into production and management methods which were at once amenable to commercial capabilities, and sufficiently superior to these capabilities to warrant Armory oversight. For a variety

[80] SAHS 2 September 1945 - 30 June 1951.

of reasons, Springfield Armory had real and perceived problems with both these tasks. When coupled with loss of bureaucratic battles within the Ordnance Department during periods of military cost-cutting, these problems led to the closing of the Armory in the 1960s.

The Armory's research and development problems were deeply rooted in its own history. Generations of commitment to weapons production, and to minimal disruption of manufacturing methods, continued to color design development. Design evaluation included assessment of whether existing equipment and tooling could manufacture a new product, especially in rifle development. The M1 development program had been a striking exception to this pattern, but it had also been largely a one-man success story, which ended happily only after the Army realized by 1919 that a magazine rifle could not easily be turned into a semi-automatic one. Contradictory military demands for new small arms, with almost impossible combinations of requested functions and capabilities, only exacerbated this situation after World War II and the enormous investment in an M1-making plant. Although the Armory succeeded with many new designs and innovative production methods from c1946-1960, it encountered embarrassing problems in its primary design mission during this period.

Creation of a lightweight rifle, with both .30” cal. killing power and fully automatic operation, proved to be an impossible assignment. The resulting M14, authorized in 1957 after more than a decade of work, could not meet all conflicting operational demands. Widely-publicized M14 accuracy and private manufacturing problems were attributed in part to Armory failures of design and product engineering. Limited Eisenhower-era funding for ground forces during the research phases, and unrealistic Ordinance Department scheduling for M14 production, contributed to these failures. The department's insistence that the Armory set up a prototype production facility, prior to completing an engineering study of the rifle, led to investments in specialized but sometimes inappropriate equipment by Winchester. Neither this firm's new investments, nor Harrington & Richardson's reliance on M1 production lines, could meet M14 production schedules. Accuracy problems proved to be a function of ammunition quality, which when improved made the M14 extremely accurate. Regardless of its relative responsibility for such faults, the Armory lost important ground politically. Colt Industries' bid to replace the rifle with a model of its own--which

became the M16--also included some exaggeration of M14 problems.[81]

Post-World War II Armory problems in production and production management were of a somewhat different nature, originating largely with the Ordnance Department's preference for private contracting. Armory practice, which now had to support rather than constrain contractors, could no longer operate outside a direct, comparative context of commercial efficiency and cost-effectiveness standards. If such standards were to regulate competitive procurement, then Springfield had to work with the same standards in developing production and quality control systems. Comparisons with private firms were rarely unbiased in this period, however, and the Armory often looked far worse on paper than it was in practice. Restrictions on Armory M14 production volume to limit competition with private firms, and costs of Armory aid to M1 and M14 contractors with severe component problems, tended to increase Armory overhead. With the exception of one M14 contractor--TRW--which built a plant designed specifically for the weapon, however, Springfield Armory outperformed all private M1 and M14 manufacturers until the cessation of M14 production in 1963.[82]

This success occurred despite Korean War production difficulties, and extensive re-use of M1 equipment and tooling for the M14. By attempting to introduce new M1 quality controls c1951-52, apparently with narrower tolerances than pertained in World War II, the Armory made its own mobilization for new wartime M1 production difficult. Hindered by such renewed conservatism and external factors such as steel shortages, Korean War productivity at the Armory was little if any better than during World War I. The wartime workforce, 35% of which was female, rose to more than 7,700 but produced only about 200,000 M1s during the period of hostilities (Figure 1.1).[83] A large supply of stored rifles made in World War II diminished the effects of Korean War rifle supply problems on the Armory's image, as did to some extent the failures of private M1 contractors.

[81] The best summaries of M14 development, production, and performance issues are in Ezell, <u>Controversy</u>, and R. Blake Stevens, <u>U.S. Rifle M14 from John Garand to the M21</u>. We are indebted to Richard Harkins for insight into M14 manufacturing and accuracy problems.

[82] SAHS 1951-1963; Ezell, Controversy, pp. 139-57.

[83] Korean War-era M1 production problems are not yet well documented, but apparent discrepancies between components made with World War II tooling, and post-1944 gages and inspection standards, appear in SAHS 1 July 1951-31 December 1951, pp. 80-85, and SAHS 1 January 1952 to 30 June 1952, pp. 102-3.

Continuing commitment to M1 equipment and tooling was a different problem. Under pressure from the Ordnance Department, lacking support for extensive plant improvements, and always hopeful of limiting time-consuming re-tooling, Armory engineers maximized the use of older equipment in engineering the M14. Sophisticated production planning and some new processes, such as carbide tool machining of wood and analog computer testing of design modifications, made Armory M14 manufacture a relative success.[84] The Armory met its M14 quotas, and made about 150,000 M14s from 1959 to 1963 (Figure 1.1). It was unable to establish production lines specifically tailored to the new rifle, however. While Armory methods provided important quality controls for the private contractors, no new methods emerged that were clearly superior to those of some private firms. Springfield could not maintain a reputation for having irreplaceable rifle production lines.

In an era of limited Army funding, Armory managers were unable to translate production capability into bureaucratic strength. Ordnance Department reorganizations in 1955 and 1963 first removed most of the Armory's procurement responsibilities, and then led to a recommendation for removal of all remaining Armory research and development roles to Rock Island Arsenal. Under the shadow of the M14 problems, and without ever having developed a politically viable counterargument to private procurement, Springfield Armory was eliminated by top Army military and civilian personnel between 1964 and 1968.[85] The transfer of Springfield Armory roles to Rock Island was not successful, leaving the Army without effective means of developing its own designs or controlling the production engineering and quality of its purchased small arms. The Springfield Armory properties survive today in a number of parcels, one of which is owned and maintained by the National Park Service as a National Historic Site.

ABBREVIATIONS IN NOTES

ARCO	U.S., Ordnance Department, Annual Report of the Chief of Ordnance to the Secretary of War for the Fiscal Year Ended June 30, ----.
ARSA	Annual Report of Operations at the Springfield Armory. Titles vary, and reports appear in different archival sources, as noted.

[84] e.g., Thomas A. Moore and William P. Goss, The Springfield Armory: A National Historic Engineering Landmark.

[85] Edward C. Ezell, "The Death of the Arsenal System: The Decision to Close Springfield Armory."

RG 156/	Record Group 156, Records of the Office of the Chief of Ordnance, National Archives. Record entry number follows slash.
SAHS	Springfield Armory Historical Summary for the Period ----, on file at Springfield Armory National Historic Site. These are semi-annual or annual reports covering the years 1951-1965.
SANHS	Springfield Armory National Historic Site. This refers to material held by the National Park Service at Springfield.
SFSA	Statement of Fabrications, Other Work Done…at National Armory, Springfield, Mass. Titles vary. These records, in RG 156/21, appear to be the only available summaries of annual operations c1865-93.

Chapter 2

THE ORDNANCE DEPARTMENT AND THE ARMORY: MILITARY POLICY AND SPRNGFIELD PRODUCTS

Since the early 19th century, the U.S. Army has relied for weapons and other materiel on its Ordnance Department, or recent successor agencies. For most of the period 1815-1963, the department's responsibilities included selection, procurement, storage, and repair of all classes of armament used by American land forces. In weapons selection and procurement, there were varying combinations of purchase from private firms and departmental research, development, and manufacture. Until World War II, Ordnance Department officers strove to limit reliance on commercial procurement except in wartime. Between c1840 and 1900, the department succeeded in this goal for rifles, small arms ammunition, and some equipment, while relying in part on purchases for other small arms and ammunition, and for heavy ordnance including gun carriages. All department arsenals issued ordnance supplies, most were also responsible for storage and repair, and a few served principally as manufacturing facilities.[86] Springfield Armory was one of two original posts established to make shoulder arms, and took the lead in freeing the Army of reliance on contractors for its muskets by c1850. From the Civil War to the end of World War II, Springfield served as the Ordnance Department center for development and production of small arms, making most of the Army's rifles. Dramatic changes in procurement policies after World War II shifted the Armory's mission to research, development, and technical oversight of weapons designed primarily for commercial production.

Armory personnel were largely responsible for the relative success with which they met small arms design, testing, and production problems. Superintendents or commanding officers, assisted by master armorers and department or shop managers, made most major decisions regarding production methods, shop management and lay-out, and flows of material, while identifying desirable new facilities requiring approval and funding in Washington.

Despite considerable Armory autonomy, institutional limits outlined in this chapter shaped much of

[86] E.g., ARCO 1904, pp. 3-4.

the direction and pace of Armory practice. There were fundamental differences between private firm or plant management and Springfield Armory operations. Some of these differences, such as lack of fire insurance or sales costs, very low interest costs, and relatively low manager salaries, characterized all federal manufacturing arsenals and shipyards.[87] The Armory, along with many other government installations, was also a branch or division of a larger agency, lacked autonomy in securing its own funding, and frequently lacked complete autonomy in selection or design of its products. Unlike a private factory, however, public funding guaranteed continued operations even during periods of limited economic growth, allowing the Armory to maintain a reservoir of arms-making skills and attracting workers with steady employment.

In this chapter, we review the interplay between Ordnance Department policies and Armory management, and then describe the weapons which were the Armory's principal products for the department. The industrial practices of the Armory, on which this report focuses, emerged largely in response to demands for large-scale manufacture of these weapons so as to meet evolving standards of interchangeability. Defining and measuring interchangeability was a paramount consideration in Armory manufacture, and warrants extended discussion in Chapter 3.

A. Ordnance Department Mandates and Military Policy

Small Arms Procurement Prior to Ordnance Department Control, 1775-1815

Design and production of American military small arms remained relatively static during the nation's first forty years, even after the 1794 establishment of two national armories to supply the regular or standing army.[88] Revolutionary and early Federal military planners paid far more attention to design and construction of heavy ordnance, for which there were no domestic sources in 1775, than to small arms. Preference for the French Charleville musket design, a long colonial tradition in rifle and musket manufacture, and a general availability of some imported European small arms all contributed to a virtual absence of concern for the design of small arms until the War of 1812. Instead, the earliest American governments purchased small arms from domestic craftsmen or from foreign suppliers, dividing authority among officials responsible for procurement, inspection, and storage, and necessarily accepting a wide variety of weapons types despite a

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[87] William Crozier, Ordnance and the World War, p.23; Hugh G.J. Aitken, Scientific Management in Action, pp. 53-4.

[88] U.S. Statutes at Large I, p. 352.

preference for French muskets.[89]

Until 1792, the War Department or its predecessors handled all military small arms management, through a Keeper or Superintendent of Military Stores. With post-Revolutionary financial problems and distrust of military power, the Treasury Department took over procurement until 1798, when the power to contract and store ordnance returned to the War Department without well-established means to inspect arms purchases.[90] By 1798, partisan Republican opposition to national armories and large arms purchases yielded to concerns about dependence on arms imports and a possible war with France when that country was America's principal foreign musket supplier. To expand the limited production of Regular Army ordnance then possible at the national armories, the Congress at this time allowed for private contracts with domestic arms makers, designating more than 60% of the appropriation for musket purchase. Despite the new call for arms, there were inherent checks on armsmaking at the Springfield and Harpers Ferry national armories. Decades of heavy reliance on small arms purchase, uneven quality control of arms purchased, limited military authority to produce or design new weapons, and inattention or active resistance to standard small arms designs created significant problems. When coupled with an extremely undeveloped domestic manufacturing base, incapable of meeting contract demands, these problems made procurement of reliably consistent weapons chimerical.[91]

Before 1815, only the Secretary of War was directly responsible for small arms design. The United States relied on a French military musket used during the Revolution, described in detail later in this chapter, as a model for American production by the national armories or private contractors. In practice, however, the relatively limited output at the armories and the effective absence of manufacturing standards for contract arms led to purchase of a wide variety of small arms types.[92]

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[89] Edward C. Ezell, "The Development of Artillery for the United States Land Service before 1861," pp. 49-76, "The Search for a Lightweight Rifle," pp. 28-31.

[90] The Treasury Department retained the power to actually pay for military stores until 1812.

[91] Derwent S. Whittlesey, "The Springfield Armory," chapters II and III; Constance M. Green et al. The Ordnance Department, pp. 14-15; Merritt R. Smith, Harpers Ferry Armory and the New Technology, p. 28, and "Military Arsenals and Industry Before World War I," p.25; Russell F. Weigley, History of the United States Army, pp. 61, 81, 92-3, 108.

[92] Despite calls by the Treasury Department's Purveyor of Public Supplies for pattern muskets to control private contractor products as early as 1808, when arming of the militia began in earnest, standard pattern muskets emerged only after the War of 1812; see Wadsworth to Dallas, June 10, 1815, RG 156/5, and George D. Moller, "Early American

The Secretary of War directed at least two conflicting lines of authority over small arms production and procurement at the Springfield Armory prior to 1815. A paymaster, subordinate to the War Department's Superintendent of Military Stores,[93] was responsible for procuring contract arms as well as materials needed to produce small arms at the Armory. The civilian Superintendent of the Springfield Armory reported directly to the Secretary of War and directed small arms production without control of his own supplies. The paymaster's higher salary reflected the emphasis in this period on purchase rather than production to meet the greater part of military requirements, while his responsibility to inspect acquired weapons evidently extended to Armory products as well as contract purchases. The paymaster could thus control what the superintendent received to produce new arms, and judge Armory production results, without responsibility for assuring adequate supplies of raw materials and tools. With no common measures or standards for arms quality, this situation led to repeated conflicts between Springfield Armory superintendents and paymasters, and generally tended to restrict quantitative or qualitative increases in Armory production. Lack of coordinated efforts by the two national armories exacerbated production problems, as did limited appropriations for Armory personnel or improvements before 1808, when potential conflict with Great Britain loosened federal purse strings and led to an act for arming the state militias by contract.[94]

The Ordnance Department, created on the eve of the War of 1812 under Commissary General of Ordnance, Decius Wadsworth, did not at first fully address small arms acquisition. The department's principal mission at this time was to contract for and inspect cannons, with a secondary mandate to inspect, supply, and maintain other ordnance including small arms. Organizational tensions along lines of divided authority peaked during this war, because of both the pressure to provide greater numbers of small arms and the somewhat uncertain status of the new Ordnance Department. The Superintendent of Military Stores became the Commissary General of Purchases in 1812, when the War Department regained complete control of its purchases during the reorganization of the Army

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Pattern Muskets."

[93] This official, also known as the Superintendent of Military Supplies prior to 1812, directed procurement of small arms and other supplies, as well as small arms inspection prior to 1812, when the new Ordnance Department took over the latter function; cf. Weigley, pp. 108-24 and Ezell, "Artillery," pp. 77-87.

[94] Whittlesey, chapter IV; Smith, Harpers Ferry, pp. 53-106.

which included establishment of the Ordnance Department. The Commissary General and his paymasters continued to have authority over procurement of small arms, a new Quartermaster-General was to procure other military stores, and the armory superintendents continued to manage production at the Secretary of War's direction. Pervasive confusion prevailed about definition of these various overlapping spheres, under a civilian Superintendent General of Military Supplies. Commissary General of Purchases, Callender Irvine, complicated wartime procurement by disputes with the Ordnance Department and by trying, for the first time, to introduce interchangeable arms manufacture on an undeveloped armsmaking industry (Chapter 3).[95]

At Springfield, the Secretary of War's June 1812 directive to the paymaster to inspect and repair arms stored since c1800 created new confusion over who controlled the nature of work done in Armory shops. Arms repair had never before been a major Armory activity, and responsibility for completed or stored arms rested with the paymaster and his superior, whose mandate focused on the arsenal's storage facilities at the Springfield site. Springfield Armory's superintendent Benjamin Prescott objected, preferring to manufacture better muskets than those previously collected or rather haphazardly made. Secretary William Eustis overruled him, hoping to arm quickly as many troops as possible. This insistence, coupled with an overcharged proof inspection system established by Eustis over Wadsworth's objections, led to a sharp wartime decline in Armory production, reversing a growth in output which began in 1808 after military appropriations increased. The first attempt to centralize all Armory activities under the Ordnance Department failed in Congress in 1813, and weapons repair and alteration continued to dominate Springfield activities during a war in which small arms were generally plentiful but of extraordinarily varied quality and origin.[96]

Establishing Uniform Production Standards and Methods, 1815-1841

The uneven nature of small arms procurement and quality, apparent long before the end of the War

[95] James A. Huston, <u>The Sinews of War</u>, pp. 103-104; Smith, "Military Arsenals..," p.28.

[96] Whittlesey, chapter IV; Weigley, p. 124; Huston, p. 106; Prescott to Wadsworth, June 29 and July 15, 1815, RG 156/21; Wadsworth to Armstrong, March 12, 1813, RG 156/5. Gen. Henry Dearborn, a former Secretary of War, instigated perhaps the most dubious arms alteration program of this war when he ordered about 7000 older muskets shortened at the barrel with the bayonets soldered and brazed, with similar bayonet treatment for about as many other unshortened muskets. This order by a field officer, also obeyed over Wadsworth's objections, added additional confusion to the question of procurement authority; the presence of 12-15,000 of these weapons later dismayed Roswell Lee when he arrived to run the Armory in 1815. Wadsworth to Prescott, July 6, 1813, and to Moor, July 7, 1813, RG 156/3; Lechler to Monroe, October 21, 1814, RG 156/21; Lee to Bomford, June 7 and June 22, 1815, RG 156/1351.

of 1812, provided Col. Decius Wadsworth with the opportunity for which he had lobbied throughout the conflict. Soon after the Treaty of Ghent, he secured for the Ordnance Department the authority to run the national armories and to contract for small arms, putting all Army ordnance under unified management for the first time. Continuation of the earlier control of armory superintendencies by presidential appointment contributed to both strengths and weaknesses in an autonomous production system described below.[97] Wadsworth's expanded domain also encompassed production, procurement, and storage of most other Army materiel at three arsenals established during the war (at Pittsburgh, PA, and at Watervliet, and Rome, NY), and five others authorized shortly thereafter (at Augusta, GA, Baton Rouge, LA, Frankford, PA, Watertown, MA, and Pikesville, MD). Ordnance Department priorities under Wadsworth (chief 1812-21) and his successor George Bomford (Chief 1832-48), however, clearly focused on manufacture of uniform, reliable small arms and cannon for the army. For a variety of technical, administrative, and political reasons, there was only limited progress in artillery manufacture for about twenty-five years, and department efforts before 1840 concentrated heavily on small arms manufacture at Springfield and Harpers Ferry.[98]

Sustained Ordnance Department and Armory efforts led to significant organizational and manufacturing advances in this period (Chapters 3-7). There were also important negative factors allowed for pursuit of the mechanized, gage-controlled uniformity of what became known as "armory practice." The relatively small scale of the antebellum United States Army and its wars precluded demands for rapid increases in production, and output at both national armories reflected instead the pace of internal progress relative to long-term Ordnance Department goals. The War Department, seeking a larger reserve of muskets than the national armories could produce for some years, succeeded in securing appropriations for as much federal production as possible. Springfield Armory output remained relatively constant from shortly after 1815 until the late 1840s, except for

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[97] U. S. Statutes at Large 3: pp. 203-204; some of our treatment of Ordnance Department objectives follows Merritt Roe Smith's third and most developed account of the department's antebellum importance, in "Army Ordnance and the `American system' of manufacturing, 1815-1861," as well as his Harpers Ferry, pp. 106-13, 194-202. Whittlesey, Chapter V, and Constance M.Green, "History of Springfield Armory," Book I, cover the civilian superintendent issue in detail for this period.

[98] Huston, p. 114; Ezell, "Artillery," pp. 90-116; Smith, "Army Ordnance," pp. 51, 70-2. For eleven years after an Army reorganization in 1821, the Ordnance Department was merged with the Corps of Artillery, retaining separate but subordinate status. Bomford remained the principal ordnance officer, and though the arrangement hampered artillery development it apparently had limited effects on work at Springfield, where the Armory remained under Roswell Lee's strong management through the department's independent re-emergence in 1832.

low-output episodes incurred during adoption of new designs after 1840 (Figure 1.1). Until the introduction of percussion weapons into European armies c1840, there was also a very limited range of available designs considered reliable enough by American ordnance officers for standard Army and militia use. The department saw the only earlier serious alternative to the French-based flintlock musket or rifle, John Hall's breechloading rifle, as too costly for large-scale production.[99] Section B of this chapter reviews the stability of musket designs produced at Springfield before 1840, and the infrequent changes made in all U.S. military shoulder arms between the Revolution and the end of the Civil War.

Given forty years of procurement problems, and initial lack of Ordnance Department authority to design weapons, virtually all ordnance officers in 1815 concurred with an emphasis on arms production rather than design or development. This emphasis, which remained a hallmark of Army ordnance until after World War II, involved establishing manufacturing standards and methods for increased output, quality, reliability, and uniformity, not on designing better weapons or on adapting weapons to changing tactical realities. During the first two decades of Ordnance Department control over small arms, minimizing changes in performance requirements (e.g., weight, range, caliber) was a deliberate and highly self-conscious means of holding products more or less constant while improving on manufacturing and procurement procedures. Roswell Lee argued the value of adhering "to a uniform pattern than to be frequently changing, although the model may not be the most perfect."[100]

Private inventors often approached the Secretary of War with new weapons designs, but a small coterie of Ordnance Department personnel, and some contractors made virtually all of the essentially minor small arms design changes before 1840. As discussed in Chapter 8, these groups usually worked in this period under informal frameworks with almost no resemblance to "research and development" other than limited experiments in the early 1830s comparing French and

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[99] Smith, Harpers Ferry, p. 194. Smith's work on Hall in this book suggests that some of the inventor's manufacturing methods were initially too advanced for general use at the national armories, although we argue in Chapter 7 that the problem may have been the immediate usefulness of Hall's methods for large-scale manufacture.

[100] Lee to Senior Officer at the Ordnance Department, November 20, 1817, RG 156/1351. Ezell reviews the emphasis on production, and its implications for later Army small arms design, in "The Search for a Lightweight Rifle" and The Great Rifle Controversy; also see Green et al., The Ordnance Department, p. 17.

American muskets. With occasional borrowings from French flintlock models--the basic design template through this period--most of these changes reflected attempts to adapt muskets to evolving means of interchangeable manufacture. Springfield Armory personnel figured prominently in early model changes, but were by no means always paramount, and the models produced at the Armory in this period were Ordnance Department designs. The department became responsible for ordnance design in 1834, but stressing production rather than design continued after what was a rather formal change in small arms procurement. Full Ordnance Department design authority tended to discourage inputs from line officers or private individuals by erecting formal testing and evaluation hurdles, administered after 1839 by a permanent Ordnance Board within the department.[101]

In developing a policy of procuring reliable weapons, the department and its arms makers focused first on measurable standards of interchangeability. The origins and definitions of this focus were not always mutually understood among department officers, but by 1840 Springfield Armory had developed an effective gaging system and was gradually mechanizing its operations to produce interchangeable muskets on a large scale (Chapters 3 and 7). An irony of Army Ordnance small arms history is the extent to which improved and often innovative manufacturing methods discouraged improvements in weapons design. Although frequently abetted by line officer conservatism, a persistent fear by ordnance officers of upsetting hard-won gains in manufacturing and quality control accounts for most of this dichotomy, and represents perhaps the darkest ordnance inheritance of the War of 1812. The armories, especially Springfield, had a critical role in executing an ordnance policy initially longer on ideals than on practical experience, and in defining an essentially conservative revolution in industrial innovation. Significant advances in management and manufacturing concentrated first on maximizing the output of high-quality weapons, and led to later emphases on minimizing disturbance of established, hitherto successful practices.

[101] Smith covers much of the 1815-40 design framework in Harpers Ferry, pp. 106-7 and 280-81, including the continuing imprint of French designs on American ordnance. The small circle of designers is highlighted by comparison of his account with Ordnance Department registers of all correspondence relating to experiments, inventions, and improvements, RG 156/192, 193, 199. See Green, "Springfield Armory," Vol I, pp. 48-9 on early experiments. As late as 1830, the Ordnance Department sent Lt. Daniel Tyler to France in search of possible production hints, although during the ensuing decade indigenous improvements by the department and its contractor, John Hall, moved well beyond contemporary European arms manufacturing practice; see U.S., Ordnance Department, A Collection of Annual Reports and Other Important Papers..., vol. I, pp. 185, 202-3. The importance of the permanent Ordnance Boards, noted by Smith in "Army Ordnance," p. 70, was initially probably more positive for artillery development than for small arms.

A strengthened post-war Ordnance Department had far greater control over the national armories than any of the earlier plethora of offices claiming divided authority, but Armory autonomy over most innovations or production methods also increased under the new regime. Armory control of actual small arms production methods defined many Ordnance Department manufacturing standards, and by the Civil War defined what the department considered permissibly possible in small arms design. Practice became policy, policy became design, and innovation became an entrenched standard within two generations.[102]

Superintendent Roswell Lee, maneuvering in tandem with his counterpart James Stubblefield at Harpers Ferry, quickly wrested command of armory finances from the paymasters within eighteen months of arriving in Springfield, putting the superintendents in charge for the first time of all armory operations, including repairs and storage.[103] Since Ordnance Department objectives in 1815 required new industrial practices, Wadsworth and Bomford found that while they could direct abstract policies of ideal new production standards from Washington, they could not always develop, specify, or control the means used to achieve the standards. The armories really defined the pace and often the nature of innovation and evolving systems of inspection, despite department-wide regulation. Essential differences between bureaucratic administration and factory management--which defined much of an armory command--gave armory superintendents an advantage in explaining and implementing what they chose to do, until men with manufacturing arsenal experience became chiefs of ordnance.[104]

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[102] Smith stresses the importance of evolving Ordnance Department administrative controls in this period, and views policy execution problems as local political and cultural ones under civilian superintendencies, in "Army Ordnance," pp. 66-70, 81-83, and in much of Harpers Ferry. His research accounts for much of the department's organizational direction and problems, and documents the sometimes dramatic differences between its two armories as well as, more implicitly, the importance of their capabilities in defining the success of department policy. He deals somewhat less fully with how the nature and origins of actual armory small arms manufacturing practice affected such policies.

[103] Whittlesey, chapter 4.

[104] Although Wadsworth and Bomford had clear visions of service-wide ordnance uniformity, no one with field installation experience became Chief of Ordnance before 1848, when former Watervliet arsenal commander and department inspector George Talcott succeeded Bomford. Talcott's inspector's familiarity with the Armory, and brief stint as acting superintendent in 1833, did not necessarily extend to real understanding of small arms production processes, however, as we suggest in Chapter 3. The first Chief of Ordnance with real small armsmaking experience was James W. Ripley, whose service prior to his 1861 appointment included thirteen years running the Armory (1841-54). Ripley's antipathy towards wartime model changes reflected knowledge of manufacturing realities as well as an extreme belief in the department's production mission; e.g., Ezell, Rifle Controversy, p. 9.

Armory responsibilities after 1815 included not only production and repair of small arms, but encompassed creating pattern arms for contractors, making gages for inspection of contract arms or arms components, inspecting contract as well as armory products, building or procuring the tools, gages, materials and facilities needed to do all of the above, managing large labor forces to meet production standards and output expectations, and most critically--recommending Armory practices and required materiel. Establishing a separate office to inspect contract arms in 1830 relieved armory superintendents of a time-consuming and often stressful administrative tack, but did not diminish their continuing control of the hardware and techniques needed to conduct such inspections. Some dissonance between Washington intent and armory practice probably persisted, in diminishing form, until large-scale production of fully interchangeable small arms emerged in the 1840s.

Roswell Lee's managerial reforms, and his successful introduction of mechanized stock-making and better barrel manufacturing technology, eliminated the most serious problems facing Army small arms procurement in 1815, and created a solid base at Springfield for introducing advances in metalworking and lock-making after his death in 1833 (Chapters 5-7). These successes left two persistent problems--contracting for parts and complete arms, and department control of armory superintendents--unresolved.

With Lee's encouragement, Colonel Wadsworth initiated an attempt to contract for parts, with final assembly at the armories, to limit reliance on contractors, lower arms costs, and increase national armory output. This policy met with some success c1817-33--especially in procuring barrels, bayonets, and ramrods--but did not reduce contracting for complete muskets, or inspecting purchased arms and parts, as major components of Ordnance Department tasks.[105]

Civilian appointment of armory superintendencies, subject to increasing politicization under Andrew Jackson, was the department's Achilles' heel throughout this period of technical innovation. Although Lee favored this system as a barrier to line officer interference with design and

[105] Wadsworth to the Secretary of War, January 27, 1817 and December 6, 1819, RG 156/5; Lee to Bomford, February 20, 1818, RG 156/21; and "Contracts for Ordnance, Supplies and Construction 1806-1918," RG 156/1382. Ambiguous data suggest possible limited parts contracting before 1815, in "Journals of Receipts and Expenditures 1794-1811," RG 156/1380.

manufacture requirements, some of his achievements in labor organization and barrel quality deteriorated under his successor, John Robb (1833-41). Reliance on Armory autonomy to reach Ordnance Department goals could succeed only with able superintendents, since in this era it was hard to remove such men if they proved unfit. Robb provided less innovative or aggressive leadership than Lee. Senior armorers and mechanics probably had greater responsibility under Robb, and made major improvements in mechanized uniformity during his tenure. However, lack of administrative direction delayed conversion of disparate technical achievements into a more unified system of production. Full integration of Ordnance Department and Armory administration after 1841 contributed to both improved plant management and a greater Armory role in establishing design priorities.[106]

Codifying Innovation and Design:

Ordnance Department Development of an Industrial System, 1841-1865

Armed with new reports on the efficiency of military arsenal administration in Europe, the Ordnance Department took advantage of the 1840 Whig presidential victory to participate in an attack on the Democratic spoils system, gaining full control of all appointments at department facilities by 1842. At Springfield and Harpers Ferry, Colonel Bomford anticipated this victory and advanced the cause of military command by securing the superintendencies for department officers in 1841. The new order not only changed their titles to commandants, but confirmed their authority over all other armory personnel, including the paymasters.[107] Coordination of department policies and objectives improved under the military regime, for reasons in addition to the simple removal of potentially dubious political appointees and their ties to often self-serving business interests. In contrast to the first generation of Ordnance Department authority over national armories, when undeveloped industrial techniques made the department extremely dependent on the initiative and expertise of a few men, Bomford and his successors prior to the Civil War had as subordinates a cadre of officers with years of experience in ordnance manufacture. This experience formed the basis for more consistently informed arsenal or armory administration and for practical experimentation in design and material problems.

[106] Whittlesey, Chapter 5; Green, "Springfield Armory," Vol. I, pp. 60-8.

[107] Whittlesey, chapter 6; Smith, "Army Ordnance," p. 83.

Networks of officers at several installations conducted mechanical, ballistics, metallurgical, and gunpowder experiments between 1841 and 1855, assisting the department in selecting or developing new small arms designs, and establishing procedures for substantially different types of design evaluations made after 1861. Virtually all such research remained focused on immediate production problems, continuing Ordnance Department emphases from the past. This approach produced increasing dissonance between military small arms design and the tactical implications of new patent weapons during this period, but also produced a military industrial system capable of arming millions of men during the Civil War. The department's ability during this war to produce or procure large numbers of somewhat outmoded small arms reflected the strengths and weaknesses of a bureaucracy grounded in independent armory and arsenal management, and relatively insulated from external pressure on its design decisions by its control of testing and evaluation. Continued, even increased, autonomy of the field installation commands made the abilities of individual managers critical in capitalizing on pre-1840 technical advances, but greater depth of officer experience often counteracted the problems of centrifugal authority seen earlier. Strong administration at Springfield under Maj. James W. Ripley (commandant 1841-54) moved the Armory towards rationalized plant improvements and increased output, built upon previous mechanical innovations. Under his leadership, the Armory finally achieved largely mechanized production of essentially interchangeable small arms in the late 1840s, but in doing so the focus of innovation narrowed considerably to overcome specific impediments to manufacture.[108]

Military command of the armories never removed the Ordnance Department from political influence, especially when civilian personnel, contractors, or suppliers approached Congressional representatives, and by the early 1850s the department's control of small armsmaking was under attack by a variety of interests. Most vocal were local opponents of military rule, seeking return of the patronage in jobs, wages and supply contracts which the commandants often curtailed. Ripley's aggressive approach to land acquisition, and sometimes strong encouragement of partisan support among his personnel, further exacerbated the situation at Springfield, where feuds and lawsuits simmered and erupted through much of his tenure. The balance swung against military commands

[108] U.S., Congress, House, Superintendents of National Armories ..., pp. 91, 95, 164, on achievement of interchangeability; ARSA 1845-60, in RG 156/1354; Whittlesey, chapter 6; Green, "Springfield Armory," Vol. I, pp. 75-80; Smith, "Army Ordnance;" John Milner Associates, "Historical and Archeological Survey of Frankford Arsenal," pp. 98-104.

with the ouster of George Talcott as Chief of Ordnance in 1851[109] and the Democratic presidential victory of 1852. After military and Congressional hearings in 1853-54, President Pierce in 1854 reinstituted civilian superintendencies, which lasted until permanently removed at the start of the Civil War. Although the return of civilian rule reversed or slowed technical progress at Harpers Ferry, Ripley's accomplishments at Springfield were so substantial, and his successor James Whitney (1854-60) was so able and politic, that the Armory continued to make important advances in plant reorganization and remaining technical problems in barrel manufacture.[110]

One line of argument against national armory management during the early 1850s was the supposedly higher cost of small arms relative to private contractor capabilities, and the suggestion that private industry was better suited to supply military requirements. Secretary of War Jefferson Davis' rebuttal, repeated during a similar campaign in the late 1870s, was that Ordnance Department costs were in fact lower and that national armory expertise was necessary to assure small arms quality, continued improvements in manufacturing methods, and the validity of costs claimed by any private contractors. Davis' arguments prevailed,[111] but the appearance of the contractor issue reflected several fundamental changes in American small arms development after c1840 with long-term implications for the effectiveness of Ordnance Department policy and organization.[112]

Earlier department successes in mechanized innovation and musket design had led to increasing divergence in the weapons designs and financial structures of public and private arms makers. The increased rigors of Ordnance Department demands for gaged uniformity discouraged many older private firms from continuing to make contract arms, as did the department's diminishing interest in supervising and inspecting their work, given its own growing industrial capabilities. The department

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[109] Talcott was a strong advocate of military command; his 1851 court-martial and removal over handling of a heavy ordnance contract left the commandants with the support of a less outspoken chief of ordnance, Henry K. Craig.

[110] Superintendents of National Armories...; Green, "Springfield Armory," Vol. I, p. 91; Whittlesey, chapter 6; Smith, Harpers Ferry, pp. 298-304.

[111] Ripley's caution about requesting estimated expenditures during the Congressional hearings, and Davis' probable sensitivity to the direction of prevailing political winds, led to sharp reductions in arms manufacture appropriations for the 1854 fiscal year, but increased funding for Springfield soon followed the adoption of the Model 1855 rifle musket; see Whittlesey, chapter 6; Green, "Springfield Armory," Vol I, pp. 88-96.

[112] Talcott to Marcy, December 14, 1848, RG 156/5; Green et al., Ordnance Department, pp. 18-19; Huston, p. 117; Green, "Springfield Armory," Vol I., pp. 88-91.

gradually let more long-term, renewable, and competitive contracts after 1840 for pistols, rifles, and other ordnance it was not prepared to make in quantity, but moved away from reliance on contractors for standard weapons. At the same time, development of machine tools and better metal processing techniques--stimulated in large part by Ordnance Department contracts--encouraged the emergence of new private machine tool and small arms firms. Although prepared to take some contracts requiring government designs, the new firms differed from their earlier counterparts in their often aggressive development or purchase of patent weapons for sale to American farmers, hunters, miners, law enforcers, and professional soldiers, and eventually to foreign governments. Competitive and selective applications of armory practices, ignoring Ordnance Department standards of uniformity discouraging and slowing the development of new military designs, allowed for rapid emergence of patent arms models after 1845. As the new small arms industrial structure replaced the once closely integrated industry dominated by government support, American small arms development preceded for some four decades on two separate, military and civilian paths which only occasionally converged. The Ordnance Department found itself forced to balance military requirements and prejudices, and its existing production facilities, against the appearance of new weapons with new tactical implications. With increasingly complete and efficient rifle-making plants at its two armories, the department was reluctant to alter established practices, even when more powerful weapons appeared. Earlier department successes here returned in private form to plague ordnance officers, in situations of continuing irony: the success of methods developed to make a very limited range of military weapons had spurred a private industry which could now make weapons more powerful than the Army's.[113]

The last two antebellum decades, when the Springfield Armory converted numerous mechanical and administrative innovations into a large plant designed to make a few products, was an extremely dynamic period in small arms design. Percussion and breech-loading single-shot shoulder arms, relatively rare in the United States before 1840, became not only common, but available in designs as numerous as the varied solutions to loading and ammunition problems; the earliest commercially available repeating rifles appeared shortly before the Civil War. Visions of government contracts

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[113] Felicia J. Deyrup, Arms Makers of the Connecticut Valley, pp. 117-32; Smith, "Army Ordnance," pp. 76-8; Hounshell, pp. 46-50; Gene S. Cesari, "American Arms-Making Machine Tool Development;" Russell I. Fries, " A Comparative Study of the British and American Arms Industries, 1790-1890;" Robert A. Howard, "Interchangeable Parts Reexamined: The Private Sector of the American Arms Industry on the Eve of the Civil War."

danced in the heads of most arms inventors and entrepreneurs, who presented virtually all new designs for Ordnance Department inspection.[114] The Ordnance Department approached these developments cautiously; wary of untested innovations and the costly changes in production process needed to meet standards of uniformity and quality, but gradually opened its design procedures to include evaluation of private inventions.

The flintlock arms favored by the Army through the 1830s suffered from unreliable firing in damp conditions. Percussion ignition became a practical alternative means of firing by the early 1820s, which western European armies gradually adopted (section B of this chapter). Despite the suspicions of some senior American line officers, the Army quickly adopted percussion weapons as standard issue after 1840.[115] The Model 1841 rifle and Model 1842 musket, both percussion weapons, were the last Army shoulder arms incorporating only the expertise available from Springfield and Harpers Ferry government arms makers and a few contractors like John Hall. The latter model became the first which the department considered both fully interchangeable and made or less identically at either national armory; tampering with such an achievement was a serious matter. To minimize manufacturing changes and re-use existing weapons, the Ordnance Department converted older flintlocks to percussion until 1858-59, although production of new flintlocks ceased in 1842.[116]

Following the acceptance of percussion weapons, the earlier informal means of designing and testing weapons gradually moved in several related, overlapping new directions. At the urging of department personnel or the insistence of Congress, there were reviews of new designs by permanent Ordnance Department boards, or occasionally by special boards with broader military representation but still subject to the Chief of Ordnance's recommendations to the Secretary of War. Ordnance officers centered at the two armories developed and conducted the necessary tests on complete weapons, or experimented on possible solutions to quality or production problems posed by new designs. The new ammunition requirements of percussion arms, reviewed in section B of

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[114] Registers of Ordnance Department correspondence relating to experiments, inventions, and improvements provide vivid impressions of the pace, timing, and nature of private designs, in RG 156/192, 193, and 199.

[115] Although Ordnance Department production of flintlock weapons ceased in 1842, important line officers like Winfield Scott distrusted percussion arms, and many of the older arms were retained for use until the eve of the Mexican War; see Weigley, p. 172.

[116] Smith, Harpers Ferry, pp. 280-81; Ezell, Great Rifle, p. 5, and "Search," p. 33.

this chapter, led the department to create a third small arms center in 1848, when Frankford Arsenal in Philadelphia was assigned the task of producing percussion caps. From that date, Frankford personnel were closely involved with design problems, as cartridge and powder issues became major factors in evaluating breech-loading and repeating weapons. The most important antebellum tests included experiments between 1849 and 1855 on cartridges or bullets, rifle barrels, and primer systems which culminated in the development and selection of the Model 1855 rifle-musket specifications, and tests made on available breechloaders between 1854 and 1858 after such weapons became increasingly popular following the Mexican War. Some private inventors used Armory facilities for their own work, although they bore all costs of such assistance after 1851, and in a few cases--notably the Maynard priming system incorporated in the Model 1855 rifle-musket--Ordnance Department personnel worked with promising patent designs to assess their suitability for armory production and to adapt such designs to armory manufacturing methods. A final class of experiments involved limited materials testing to select appropriate means for making specific parts. Springfield Armory personnel, assisted on occasion by officers from Frankford Arsenal, conducted many of the latter tests at the commandant's or superintendent's discretion to achieve technical solutions to design problems.[117]

Test procedures and equipment, informed by the expertise of many ordnance officers and by contemporary department experiments in artillery development, became increasingly rigorous. Springfield Armory became an important center for such work on small arms during this period, along with Harpers Ferry and Frankford. The lack of any permanent Ordnance Department research structure, and the limited availability of specialized testing equipment, persisted until after the Civil War (Chapter 8). Despite increasing department ability to evaluate weapons, ordnance officers did not actively seek new designs from private sources, feeling constrained only to assess whether available inventions seemed superior to current Army models. With its control of testing procedures and authority to recommend all ordnance models to the Secretary of War, the Ordnance Department effectively restricted outside small arms design sources until the late 19th century, and until after World War II did not use its expertise to develop design specifications and solicit private responses.

[117] ARSA 1845-60, in RG 156/1354; U.S., Ordnance Department, Reports of Experiments with Small Arms for the Military Service; U.S., Ordnance Department, A Collection of Annual Reports..., Vol. II, pp. 405-7; Claud E. Fuller, Springfield Muzzle-Loading Shoulder Arms, pp. 85-92; Green, "Springfield Armory," Vol. I, pp. 77, 101; Huston, pp. 157, 188; Smith, "Army Ordnance," p. 73; John Milner Associates, pp. 97-100.

This approach probably had several sources: reluctance to alter production methods, professional suspicion of private weapon quality, and wariness of paying for patented designs. Regardless of cause, such policy had many adverse consequences for weapons design and production methods over the years, first becoming controversial during the Civil War.

The loss of Harpers Ferry Armory at start of the Civil War left only Springfield ready to produce the standard Army shoulder arms for Union forces. Because the Armory could not arm quickly an unprecedented number of men, contracting for parts and finished arms became an important Ordnance Department function throughout the war, despite tremendous expansion of Armory capabilities. Shortly after hostilities began, newly-appointed Chief of Ordnance James W. Ripley recommended contracting only for the regulation rifle musket, and with his perennial vigor opposed consideration of any new designs in the face of wartime production demands.[118] Procurement realities quickly led to acquisition of numerous weapons types from domestic contracts and foreign purchases, however. The Army purchased more than 726,000 European shoulder arms during the first fifteen months of war--in part to deny such weapons to the Confederacy--but thereafter virtually eliminated this source as Armory and domestic contractor production soared. Springfield expanded production capabilities dramatically, at the same time guiding more than thirty contractors in manufacture of the rifle-musket through supply of gages, models, and inspectors. The Armory's approximately 802,000 rifles manufactured during the war amounted to more than a quarter of all shoulder arms procured or fabricated by the Army, and together with another 670,000 Springfield rifle-muskets made by contractors meant that the Army's model equaled nearly half of all such arms.[119]

Privately produced and patented breechloading rifles were widely available by the Civil War. The Ordnance Department investigated and rejected their possible use as a service arm in the late 1850s. Faster to fire than the standard issue infantry weapon, breechloaders were popular with many Union

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[118] After serving as department inspector of armories, arsenals, and depots following his removal from Springfield, Ripley quickly succeeded in effecting the final removal of civilian superintendencies when he became Chief of Ordnance; see Whittlesey, chapter 6.

[119] ARCO 1862 and 1863, in A Collection of Annual Reports..., Vol. III, pp. 445, 453 and Vol. IV, pp. 844-7, 893-4, 903-4; Wiegley, pp. 235-8; Robert M. Reilly, United States Military Small Arms, 1816-1865, pp. 72-5; Ezell, Rifle Controversy, p. 9; Green, "Springfield Armory," Vol I, pp. 118-20.

troops but lacked the range or reliability of the Army rifle-musket. Without mass-produced metallic (expansive) cartridges, most breechloaders remained subject to gas leaks and worn seals; the department's own contracts, c1819-43, for breechloader rifles and carbines developed by John H. Hall provided earlier evidence of this problem. Recent, expensive development of rifle-musket production systems, and persistent line officer resistance to new weapons which might expend too much ammunition, reinforced Ripley's view that breechloaders should not be developed as standard issue during wartime. His opinion remained department policy through the tenures of himself and successor George D. Ramsay as Chief of Ordnance (April 1861-September 1864). As noted in Chapter 1, breechloader problems, wartime demands, and the need for long-range accuracy in Civil War infantry battles give much credence to Ripley's stance. However, almost 400,000 breechloaders purchased by the department for cavalry units, plus thousands more obtained privately or through state channels for infantry regiments, made a strong cumulative statement about the faster-firing weapons. By late 1864, the department began an elaborate search for a breechloader able to meet the department's somewhat procrustean standards. The search outlasted the war, and soon encountered even more lethal and controversial models.[120]

Searching for Breechloading and Magazine Rifles, 1865-1892

Military spending contracted sharply immediately after the Civil War. For two decades, Congress was reluctant to spend more on small arms than needed for the reduced post-war Army. The Ordnance Department, manned by only a handful of officers, and left somewhat on its own by prolonged and direction-sapping questions within the War Department over the relative authority of the Commanding General and the Secretary of War, faced three major problems in this era. The first two were not limited to small arms: convincing Congress of the need to fund a larger store of ordnance against the possibility of involvement in a European war; and retention of department production facilities as the principal sources of weapons supply. The third problem was selection and manufacture of a new military rifle which at once met department production quality standards, field service accuracy and firepower expectations, and contemporary European performance standards for rapid fire. As the search for acceptable rifle models became more prolonged, it exacerbated both of the department's other, more general problems by reinforcing Congressional

[120] Huston, pp. 157, 188; John Milner Associates, pp. 105-8; Carl L. Davis, Arming the Union: Small Arms in the Civil War.

reluctance to purchase large numbers of temporary design solutions, and by encouraging private arms makers to argue for entirely private procurement given the supposed costliness of public arms production in a period of limited output.[121]

The Ordnance Department repulsed an organized attack made by private arms makers in 1878-79 on the need for national armories, by documenting low production costs and repeating arguments about quality control and innovation used in the 1850s.[122] This episode was the last of its kind prior to the Vietnam War, when the Springfield Armory succumbed to a different set of arguments for private procurement of military weapons. The department retained control of production as well as the testing and selection of new small arms designs. Despite the perennial preference for department designs and production methods, however, department personnel had to rely increasingly on private designs for possible rifle models after unsatisfactory experiences with Springfield Armory solutions to the problem of a breechloading military rifle. The increased availability of magazine rifles to both American Indians fighting the Army and to European forces, in an era of continuing rapid advances in small arms design, put the department under new and greater pressure. By 1870, the Army needed to select or develop a magazine rifle, but the Ordnance Department was unable to design an acceptable one of its own. Unlike the more sporadic antebellum department responses to private designs, there was almost constant testing of patent rifles as well as department designs between 1864 and 1893, a period during which seven Ordnance Boards wrestled with rifle design selection. The Armory was the center for department rifle tests, and became an important experimental center for small arms powder and heavy ordnance testing during this period as well. Maj. James G. Benton (commandant 1868-81), prominent in small arms testing and development since the 1850s work on the rifle musket, spearheaded this activity, which after about two decades coalesced into a separate Experimental Department at the Armory in 1891, just before the last magazine rifle selection tests (Chapter 8).[123]

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[121] Weigley, pp. 285-88; Crozier, p. 4; Chief of Ordnance Stephen V. Benét's arguments for having large stocks of modern rifles to match European capabilities, and deter possible war, appear with somewhat uncanny familiarity in ARCO 1875-1878; arguments for and against retention of military arms production appear in U.S. Senate, The Cost of Manufactures at the National Armory, pp. 65-72.

[122] C. Meade Patterson, "Springfield on Trial."

[123] SFSA, in RG 156/21, 1870-92.

Growing Ordnance Department expertise in ballistics testing was not matched by effective innovation in weapons design. The post-Civil War era was notable as the first in which the department recognized that its own standards and methods were not entirely sufficient to meet its own needs. Army line officers appreciated the long-range power and accuracy of the breechloaders which remained standard issue for more than a quarter century after 1866, and some in fact found replacement of such weapons improbable, but many Indian-fighting units and ordnance officers recognized the need for more rapid-fire tactics. Commitment to established procedures reinforced by severe funding limits exacerbated department design problems. By choice or necessity, department designs emphasized re-use or conversion of existing weapons and ammunition. Springfield had an overabundance of machinery from the Civil War plant expansion, but little funding to improve machinery or plant arrangements until after 1885, when plans for new fireproof structures first emerged in anticipation of the long-awaited magazine rifle. In contrast to the average $250,000 expended annually on smallarms from 1850-60, Congress restricted annual allocations to about $100,000 through most of the 1870s. The Armory actually closed for a time in 1877 when no Congressional appropriation appeared. In such periods of uncertain Armory employment, private firms seeking "Armory practice" experience hired Armory personnel, eroding some of the human capital represented by skilled armorers.[124]

An 1872-73 Ordnance Board headed by Brig. Gen. Alfred Terry recommended a series of Springfield-designed service breechloaders used for twenty years, yet recognized that "...the adoption of magazine-guns for the military service, by all nations, is only a question of time..."[125] Repeating guns firing cartridges fed from tubular magazines first appeared before the Civil War. Some of these weapons, in particular the Spencer and the Henry (later Winchester) rifles, saw use in the war through private and Ordnance Department purchase. Spencer carbines were issued to troops in the West after the war ended, and Custer's troops had them at the infamous Washita massacre of 1868. The .50/70 Sharps single-shot carbine soon replaced these Spencer carbines in the U.S. Army, however, while the Ordnance Department deliberated over its own single-shot weapon. Between the department's first 1865 decisions on breechloaders and the Terry board's convening in 1872, the proliferation and quality of repeaters increased dramatically, requiring the department to begin

[124] U.S. Senate, Cost of Manufactures, p. 5; ARCO 1876-77; Weigley, p. 270.

[125] ARCO 1873, p. 48.

systematic considerations. Ironically, the department's own ammunition development accelerated the growth of repeater designs, since private arms makers quickly adapted the center-fire cartridge--developed at Frankford Arsenal for the Model 1866 breech-loading rifle--to magazine-fed patent models. The United States Army was the first in the world to adopt this cartridge, but many of its officers insisted on a magazine arm "...which shall be as effective, as a single breech-loader, as the best of the existing single breech-loading arms..."[126] This position effectively restrained acceptance of any magazine weapon not produced at Springfield, whose Model 1873 was a favorite of many officers. For some years, the Chief of Ordnance expected that a military magazine rifle would be a .45 caliber Springfield rifle altered to allow for magazine fire, but mechanical and ammunition problems made this view untenable. The department also created funding problems with this position: requesting large numbers of single-shot breechloaders while anticipating their obsolescence was a contradiction which probably contributed to the severe appropriation limits of the late 1870s.[127]

Congressional action restricted experimentation with new weapons in the mid 1870s (Chapter 8), but several Terry board members soon had personal evidence of the value of repeating rifles. General Terry was in command of the large 1876 expedition which included Custer's Seventh Cavalry. The disaster at the Little Big Horn, where former board member Major Marcus Reno nearly lost his life, was the best known of a series of actions in which Indians used repeaters. This spectacular defeat reversed any Congressional reluctance to fund selection of a magazine rifle design, and led to heavy pressure on the service to adopt some form of repeating small arm. From 1878 to 1892, the Ordnance Department continually worked with possible magazine systems, after an 1877 Congressional act authorizing funds for production of field trial weapons if the department could select an acceptable model. While searching for a weapon to match any possible foreign adversary, however, the department tried to allay fears of further frontier catastrophes by asserting the continued superiority of the Model 1873 for domestic wars. Springfield Armory did a study of hundreds of captured Indian firearms in 1879 to see if western tribes had weaponry superior to that of Army troops. Predictably, the study concluded that although some Indians did have repeating

[126] Ibid.

[127] Captain Stanhope Blunt, "The Modern Infantry Rifle;" Philip B. Sharpe, The Rifle in America, PP. 82-84, 219-223; Andrew F. Lustyik, Civil War Carbines, pp. 18-22; Norm Flayderman, Flayderman's Guide to Antique American Firearms, pp. 173, 268-269, 503-505; ARCO 1877, 1878; John Milner Associates, pp. 108-10; Weigley, p.268.

magazine-fed firearms, the army's single-shot arms had the long-range power and accuracy needed for trans-Mississippian warfare.[128]

Ordnance Department resistance to all available magazine systems through the 1870s and 1880s reflected the department's control over the selection process, and the solid base of support for the .45/70 Springfield among many field officers, many of whom apparently resisted the idea of a magazine arm. Army officers did not want troops wasting ammunition, fearing expenditure of the ready reserve before it was really needed.[129] Single-loading, even if slower than magazine-loading, conserved ammunition, helped maintain fire discipline, and kept the magazine's supply intact. It was also the way American soldiers had always loaded standard military rifles. In the 1892 annual report of the Chief Ordnance Officer, Department of the Platte, on the eve of final magazine rifle selection, there is a clear statement of the conservative attitude:

> The Springfield rifle and carbine have been developed to their present perfection by years of labor, and line officers and men will require to be thoroughly convinced of the superiority of a new arm before they will be ready to abandon the old reliable Springfield.[130]

The Army's commitment to its .45/70 ammunition was a major technical obstacle to development or acceptance of a magazine rifle, as other nations began using magazine arms with small caliber, high velocity cartridges. The Swiss, Portuguese, French, and British selected cartridges in the 1880s with ballistics far superior to the heavy American .45/70, by taking advantage of newly-available smokeless powder. Increased foreign firepower soon unlocked the first substantial Congressional funding for Armory plant expansion since the Civil War, in anticipation of imminent magazine rifle production, but the lack of a suitable American smokeless powder delayed the development of a proper cartridge by the Ordnance Department. In 1888, the department obtained samples of European rifles and powder charges, and began tests at Springfield and Frankford to select an

[128] ARCO 1879, pp. 303-328. Archaeological studies of the Custer Battlefield in 1984 and 1985 show "overwhelming evidence that the Sioux and Cheyenne outgunned the soldiers." Of probably 1500 warriors in the battle, "perhaps 200 carried 16 shot repeating Winchester and Henry Rifles." More than a third had one of the forty-one different types of Indian firearms identified. See Robert Paul Jordan, "Ghosts on the Little Big Horn," National Geographic, p. 797; and Douglas D. Scott and Melissa A. Connor, "Post-Mortem at the Little Bighorn," Natural History, pp. 50-51.

[129] ARCO 1878, p. 5.

[130] ARCO 1892, p. 327.

appropriate charge.[131] Progress on this issue took several years, and in 1889 Chief of Ordnance Stephen Benét acknowledged that "...in the absence of a suitable small-arms powder there has been no substantial progress in the matter of a small caliber rifle..."[132] Frankford Arsenal, eventually designated the department powder testing center, conducted tests which gave promise of solving the gunpowder problem. The new smokeless powder (an American and a Belgian type were finally found suitable) reduced residue in the barrel, thus making a smaller bore more feasible. Even with a lighter, more easily handled cartridge than the existing .45/70, smokeless powder generated greater pressure, propelling the projectile with higher velocity and a much flatter trajectory. This lethal development increased effective killing range and reduced problems of sight adjustment. Troops could also carry more rounds of a lighter cartridge.[133]

The Army began what became its final magazine rifle selection procedures in 1890, even before all powder and cartridge problems were solved. Although it was clear by this time that the Ordnance Department's old cartridge was unsuitable, the department still hoped to retain the use of its own weapon to the extent possible. It developed several single-loading .30" caliber modifications of the Model 1873, and the Board on Magazine Arms was then asked to consider these designs and give an "...opinion as to the relative merits of magazine arm and a single loader for use in the United States service."[134] Pursuing the Army's preference for single loading, the board divided magazine arms into two general classes: 1) those which could be used as single loaders only when the magazine was empty, and 2) those in which the magazine could be fully loaded but held in reserve while the rifle was fired as a single loader. Board officers clearly intended their chosen rifle to be used as a single-loader in most situations. Captain Stanhope E. Blunt, one of two Ordnance Officers on the five-man board, wrote a separate treatise on "The Modern Infantry Rifle " in which he argued that the normal use of a magazine arm of the second class will be as a single-loader "...with the magazine always retained as a reserve." The rounds in the magazine would be saved "...for the supreme

[131] ARCO 1878-88; SFSA 1890-91, in RG 165/21; U.S., Ordnance Department, A Collection of Annual Reports..., Vol. III, pp. 529-33; Lt. Col. William S. Brophy, The Krag Rifle, p. 3; Ezell, "Search," pp. 37-38.

[132] ARCO 1889.

[133] Brophy, The Krag Rifle, p. 3; Ezell, "Search," pp. 37-38; ARCO 1898, pp. 11-12.

[134] ARCO 1892, pp. 110-112, 117-119, 181-182; Brophy, The Krag Rifle, pp. 4-6.

moment of an action...," and their presence would provide "moral support."[135]

The board examined and rigorously tested 53 guns, many of which were the standard rifles of foreign nations or variations thereon, and found that bolt action was superior to the block system of the Springfield "...in ease of manipulation, facility of loading, and rapidity of fire...," even when cartridges were loaded singly, the only way the Springfield models functioned. In a fair test with the best repeating rifles in the world, three .30" cal. Springfields did not measure up to the competition; a low-velocity, standard .45"/70 Springfield type would have done even more poorly. The best bolt action magazine arm recognized in the tests was one of the Krag-Jorgensens models, a modification of the standard Danish military arm. One of the second class of magazine arms tests, the Krag-Jorgensen used a .30/40 flanged cartridge. On the question of the "...relative merits of a magazine arm and a single loader...," the board stated forcefully that an arm such as the Krag-Jorgensen No.5, well-designed for both single-loading and magazine fire, "...to be vastly superior for use in the United States service to any weapon adapted to single-loading fire only."[136] The board placed high value on the clearly visible thumb piece that revealed whether or not the Krag's magazine was being used for loading. The thumb piece of the rifle engaged a "cutoff" which physically blocked the magazine, holding its cartridges in reserve. The board's report praised the Krag for having a cutoff which plainly indicated "to the officers which class of fire is being delivered."[137] The Danish arm thus seemed to answer both contemporary tactical problems and American preferences for single-loading, although until the Krag's fine combat record in Cuba many officers continued to claim the Model 1873 was a better arm.[138]

The Army had finally selected a magazine arm, but many Americans were not ready to accept a weapon of foreign design (Krag and Jorgensen were Norwegians). In making its fiscal 1893 appropriation for the "manufacture of arms at the national armories," Congress stipulated that "no part of this appropriation shall be expended for the manufacture of magazine rifles of foreign in-

[135] ARCO 1892, pp. 110-112; Blunt, p. 557.

[136] ARCO 1892, pp. 110-112.

[137] Ibid.; Blunt, pp. 556-581.

[138] ARCO 1898, p. 12.

vention" until a new set of magazine rifles was tested by another board. Only "if no such American invention" was recommended could the appropriation be spent to make the Krag. After further testing in 1893, in which no American rifle was found suitable, Springfield Armory prepared for Krag production.[139]

Scientific American lamented this situation in several articles, finding it "somewhat humiliating to us who pride ourselves upon our ingenuity and inventive ability." One writer for the journal stated, with less than complete accuracy, that "For the first time since this country was a nation we have set aside native talent to seek abroad for the weapon with which to arm our troops."[140] With more enthusiastic funding for small arms, however, Springfield Armory personnel now entered immediately into an era in which native talent faced demands for technical and organizational innovation not felt for some four decades, as they moved to produce and modify a weapon with relatively few components carried forward from earlier models.

Gradual Improvements and the Crises of War, 1893-1918

Following final approval of a magazine system for an Army rifle, and the alleviation of immediate pressures to provide a better standard small arm, the Ordnance Department reverted to an almost antebellum approach to small arms supply. The department recaptured virtually complete responsibility for weapons and ammunition design, and exercised its perennial preference for tailoring any new model changes to existing components and processes. In contrast to the extensive trials of patented or foreign small arms systems prior to 1893, the department returned to earlier, more introverted habits for ordnance production, striving to maximize government manufacture and limit dependence on private suppliers.

There were new aspects to the department's re-assertion of autonomy, however. Experimentation and testing in small arms design, ammunition development, and metallurgical research became permanent adjuncts to production, serving both to retain department control of design and to confront new problems in using steel components or tools. The department also focused on demonstrations to Congress of management and cost efficiency at least equal to that of private

[139] ARSA 1893, in ARCO 1893, pp. 127-131.

[140] Scientific American, June 8, 1893, p. 8, and Sept. 27, 1894, p. 4.

industry, in an effort to remain the principal supplier, designer and procurement overseer of government ordnance. Although many non-comparable aspects of costs in public and private production made many comparisons with industry technically impossible, the department continually justified its methods in the context of America's vastly expanded late 19th century industrial base. Before this period, the potential of private industry to provide much Army ordnance was more limited, and the issue of relative public/private costs surfaced infrequently. Now, measurable cost savings, as well as successful production of durable interchangeable weapons, now became embedded in most peacetime policy considerations.[141]

The difficulties involved in producing the Model 1892 rifle and its ammunition further reinforced the preference for limited changes in design and stable production costs. Springfield Armory and Frankford Arsenal developed new production facilities to meet traditional standards of department manufacture, under essentially autonomous management by the commandants. Despite earlier initiation of new shop construction at Springfield, the often radically different nature of Krag rifle components required more than 15 months of Armory reorganization before the first complete new weapon emerged from the plant at the beginning of 1894. Armory commandant Col. Alfred Mordecai directed a somewhat ruthless but generally successful program of labor saving and technical innovations which produced new carbines and rifles sufficient for all regular Army troops by May 1895 (Chapters 6-7).[142]

Springfield and--after 1905--Rock Island Arsenal remained the only suppliers of standard military shoulder arms until World War I, but such self-sufficiency was the exception in Army ordnance prior to the Spanish-American War and during its immediate aftermath. At Frankford, developing .30” caliber ammunition took more time than manufacture of the earliest version of the new rifle, and private ammunition or powder contracts remained important to c1905. In addition to powder, private contracts provided pistols, early types of machine guns, and some gun carriages and small

[141] Daniel R. Beaver, "The Problem of American Military Supply, 1890-1920," pp. 75-6, identifies the problem of private corporate examples as possible models for the Army; Aitken, pp. 50-57, provides the clearest statement of the cost and efficiency issue for the early 20th century Ordnance Department. Although the origins and evolution of the issue after c1880 remain largely unexplored, cost-cutting efforts at Springfield after 1892 suggest the powerful presence of comparisons with private industry.

[142] ARCO 1893-95; ARSA 1893-95, in ARCO.

cannon. Department officers regarded most of these purchases as temporary expedients required by limited Congressional appropriations, and, anticipating the supply of virtually all army ordnance with department-made products, made little attempt to coordinate with private industry for emergency planning. For example, a decade before it was prepared to provide nearly all small arms ammunition, Frankford Arsenal established a laboratory in the early 1890s to control development of department powder and limit dependence on private manufacturers.

Well-publicized supply and other logistical problems in the invasion of Cuba showed the Army's lack of preparation for even a small war overseas, at a time when colonial expansion and possible conflicts with European powers were no longer theoretical issues. The Ordnance Department took advantage of subsequent army-building to increase its control of design and production. Especially under Brig. Gen. William C. Crozier (Chief of Ordnance 1901-12, 1913-17), the department's response to production limits was to turn further inward, expanding weapons development of department-made prototypes, minimizing private purchases, and relying for Army ordnance almost exclusively on government arsenals. After c1907, the department achieved practical peacetime self-sufficiency for most items except some gun carriages, with the establishment of gunpowder plants at Picatinny Arsenal in New Jersey and expanded cartridge-making facilities at Frankford Arsenal.[143]

The Spanish-American War provoked at least three major changes in departmental production and design of small arms: expanded facilities including a second rifle plant; accelerated design of a new magazine rifle; and production of weapons types formerly procured by contract. Small arms problems created some of the Army's greatest embarrassments in Cuba. Repeated changes in Krag rifle design and a lack of sufficient machinery slowed Springfield production in 1898, so that of about 260,000 troops in Cuba only the regular Army had .30” caliber magazine rifles with smokeless powder cartridges. The volunteer regiments--about 80% of the expedition--had .45” caliber breechloaders with black powder cartridges. Even arming the volunteers required new equipment at Springfield to make breechloader components and bayonet scabbards, with some components procured by contract. The disadvantages of black powder, when used against Spanish troops with more modern cartridges, stimulated a defensive Ordnance Department response to accusations that the volunteers had inferior weapons. Smokeless .45” caliber cartridges were

[143] ARCO 1895-1907; Green et al., p. 19; Beaver, p. 77; Aitken, pp. 56-7.

immediately introduced for its stock of older rifles. The department also began plans shortly after the war to expand rifle production by developing a second plant at Rock Island Arsenal, but delayed work there until Springfield developed a new rifle which addressing other problems revealed by the 1898 campaigns.[144]

Although the Krag rifle performed well in the Spanish-American War, it did not measure up to the bolt-action Mauser rifles used by Spanish troops. The bolt action developed by German designer Paul Mauser had two locking lugs, and fired a more powerful cartridge of similar caliber than did the Krag. The higher-velocity projectile had a longer maximum range than the Krag bullet, and was more deadly on impact at comparable ranges because of its greater energy. The lone locking lug on the Krag could not contain the pressures created by a cartridge like that of the Mauser. Some officers were also impressed by the Mauser's capability for rapid loading from a "clip," or metal charger. Ordnance officers at Springfield had modified the Krag twice before the war. Soon after the war, they began a program--including experiments with Mauser rifles--to develop an improved service rifle and a new cartridge. Based on this work, the Chief of Ordnance asked the Armory in 1900 to test a new .30” caliber rifle using a Mauser-type bolt as a possible replacement for the Krag.

After a period of experimentation and modification, the Secretary of War ordered the production of 5,000 model 1901 rifles for trial. The Armory was still setting up to meet this order in 1902, when Gen. Crozier asked for rapid testing of 100 specially-made examples of the rifle. Enthusiastic board evaluations and additional modifications led to the approval of the new weapon and its official adoption as the United States Rifle, Model of 1903, Caliber .30, although changes in bayonet form and ammunition delayed full production until 1906 (see section B of this chapter). Fourteen years after initial adoption of a foreign design, Armory personnel and Frankford Arsenal ammunition developers completed a distinct, American rifle with some major foreign elements borrowed from Krag-Jorgensen and Mauser designs.[145]

The completion of a working rifle plant at Rock Island Arsenal by c1905 meant that Springfield was

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[144] ARCO 1898-1902; Smith, "Military Arsenals," pp. 38-9.

[145] ARCO 1899-1903;ARSA 1899-1903, in ARCO; Clark S. Campbell, The '03 Spring-fields, pp. 1-8; Julian S. Hatcher, Hatcher's Notebook, pp. 1-2; Hicks, pp. 110-112; William S. Brophy, The Springfield 1903 Rifles, pp. 2-22. For the history of Mauser rifles, see Ludwig Colson, Mauser Bolt Rifles.

for the first time in more than forty years not the sole National Armory. The older installation Pagily retained its premier role in Ordnance Department small arms work, however, after providing Rock Island with the gages, drawings, and many of the tools and components needed to start production of the new rifle. In addition to its larger rifle plant, Springfield remained the principal laboratory for small arms development, and became increasingly involved in automatic pistol and machine gun testing and production as part of the Ordnance Department's move towards autonomous manufacture. After about a dozen years of tests, the Armory by 1913-14 included plants for production of the Model 1911 .45" caliber automatic pistol and the Model 1909 .30" caliber automatic machine rifle.[146]

Even before approval of the 1903 Springfield, Armory personnel also began experimentation on self-loading rifles, the next generation of shoulder arms, after Ordnance officers became aware of European interest in such weapons. Semiautomatic, or self-loading, pistols which fired at each squeeze of the trigger were in use by 1900, and private inventors were already designing semiautomatic rifles for possible adoption by the military. The fully automatic machine guns of the late nineteenth-century demonstrated that it was theoretically possible to make a rifle load itself. While the full tactical implications of the machine gun were not yet apparent, some infantry officers recognized the need for more firepower to help overcome the advantage that fully automatic weapons gave troops in defensive positions. The bolt-action rifles used by major early twentieth century armies had certain disadvantages. The rapid operation of a bolt action rifle required manual dexterity, practice, and considerable training; natural "left handers" had additional problems and needed even more practice. Often, the manual operation could make the best soldiers lose sight of their targets between shots. The soldier's rate of accurate fire was limited by his ability to operate the bolt and to reacquire a good "sight picture" after each shot.[147]

Between 1901 and 1917, the Ordnance Department tested two dozen semiautomatic rifles, most of which proved unsuccessful and none of which the department pursued beyond experimental stages

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[146] ARSA 1901-14, SANHS.

[147] Ezell, "The Search for a Lightweight Rifle," pp.40-42, and The Great Rifle Controversy, p. 13; Melvin M. Johnson, Jr. and Charles T. Haven, Automatic Arms, pp. 29-30, 51, 64; Philip Sharpe, The Rifle in America, p. 513; John Ellis, The Social History of the Machine Gun, pp. 71, 123; author Malone's personal experience with bolt-action and semi-automatic rifles.

(Chapter 8). Although Armory personnel drew up general, flexible specifications in 1909 for a new rifle, including calls for a magazine with eight cartridges of approximately .30” caliber, in practice most effort went towards creating a self-loading Model 1903 rifle, so as to reduce expensive retooling. At least six of the rifles tested were conversions of the service arm. Standard bolt-action rifles could not withstand stresses of most self-loading, and the department could not obtain same European prototypes in an era of increasing international tension: with these problems, reliance on traditional development procedures and attitudes makes the design failure unsurprising. The Chief of Ordnance evidently felt no great urgency about the matter in the context of improving production and procurement of current ordnance, and the department never translated its general semiautomatic rifle specifications into an active search. Instead, it relied largely on private models presented for testing, or on models by personnel at Springfield and Rock Island, in an approach reminiscent of early 19th century weapons design, even though by 1910 there were a number of reliable semiautomatic hunting rifles in civilian hands. World War I brought this somewhat leisurely research to a halt as Ordnance Department capabilities to supply very large forces suddenly became a major wartime issue.[148]

Under General Crozier, the Ordnance Department enjoyed autonomy unusual among Army supply bureaus in a period of significant military reorganization. Elihu Root (Secretary of War 1899-1904) oversaw the creation of a general staff under a Chief of Staff in 1903. This change was designed in part to introduce more coordination and planning among line and supply services, in the wake of problems raised by the Spanish-American War and the occupation of the Philippines. The supply services, formerly directly responsible only to the Secretary of War, resisted the Chief of Staff’s authority but were generally weakened by a new emphasis on line officers as the principal definers of Army needs. This emphasis met line objections to decisions by a bureau perceived as ignorant of field conditions. An Army reorganization act of 1901 abolished permanent transfers to the service bureaus and made promotion possible only from the regiments, eliminating some former attractions of the bureaus and leaving them short of staff. Although his department remained undermanned until the American entry into World War I, Crozier succeeded in softening some provisions of the 1901 act by 1906, and generally resisted all influence of other bureaus or line officers on the

[148] ARCO 1902, p. 7, 1903, p. 12, and 1910, p.595; Sharpe, pp. 513-514; Ezell, "Search," pp. 39-43, and Rifle Controversy, pp. 10-19; Johnson and Haven, pp. 53-56.

recommendations of the Board of Ordnance and Fortification, established in 1888 as a permanent body including Ordnance, Engineer, Signal, and Artillery officers to review all ordnance design changes.[149]

Along with other supply services and many general officers, the Ordnance Department under Crozier insisted upon its ability to provide virtually all Army needs until American involvement in World War I became a more distinct possibility. Until the need for mobilization, Crozier generally eschewed involvement with private industry, evidently maintaining a belief in the capacity of American industry to overcome any extreme situations, especially given private involvement in wartime ordnance contracts with European powers. To accommodate his own staff shortages and to keep his department "competitive" with private suppliers, however, Crozier borrowed from private practice by attempting to introduce aspects of Frederick Taylor's scientific management after 1906, notably via outside consultants at Watertown Arsenal. Attempts to make radical changes in management methods, the short product runs, and the often non-repetitive nature of manufacturing tasks at Watertown made this venture difficult, and resulted in well-publicized labor resistance which embarrassed the department. Productivity increased significantly before World War I, however, at other installations more amenable to new means of industrial efficiency. Springfield Armory, with its long tradition of mechanized manufacture, and plant facilities set up for relatively large output of standardized products, increased its efficiency without sacrificing weapons quality in this period.

In addition to taking advantage of increased appropriations for plant and machinery during the Army's institutional response to the Spanish-American War, Springfield military and civilian managers also introduced successful labor- and material-saving procedures prior to Crozier's scientific management campaign, first in setting up for Krag rifle production under Alfred Mordecai and later in responding to Spanish-American War production problems under Lt. Col. Frank H. Phipps (commandant 1899-1907). Both these autonomous efforts by Armory commandants included enough consideration of labor issues to preclude serious implementation problems, and were later praised by Crozier as examples "...of the principles of the Taylor system although they were not

[149] Huston, p. 296; Green et al., pp. 20-21; Weigley, pp. 317-18; Crozier, pp. 4-10; Beaver, pp. 75-6; Aitken, pp. 57-61.

obtained from Mr. Taylor or his experts" (Chapter 6).[150]

Although Crozier began protesting in 1915 against too much reliance on Ordnance Department supply in the event of war, the Army generally resisted planning for an integrated wartime procurement system including civilian industry until 1916, and failed to coordinate private efforts adequately until some five months before the 1918 armistice. Ordnance Department supply failures during the first months of formal American involvement cost Crozier his job, despite several attempts at wholesale departmental reorganization along functional lines with decentralized districts. In part by delegating more authority to district civilian managers, Crozier's successor, Maj. Gen. Clarence C. Williams (Chief of Ordnance, 1918-30), succeeded in gaining on ordnance supply problems as the war ended, by which time the department's reputation remained clouded.

Springfield Armory's production of the Model 1903 rifle was symptomatic of Ordnance Department strengths and weaknesses as the United States entered World War I. The rifle was a superbly made, fully interchangeable, extremely powerful weapon, made with somewhat antiquated means and an attention to precision which no private manufacturer would wish to emulate. Armory production, buttressed by smaller output at Rock Island, was adequate to arm the peacetime Army with a reserve of about 600,000 rifles in 1917, but was not capable of full wartime demands. As with the Civil War, the Armory had to rely on civilian contracts to fulfill Army demands, but unlike the Civil War, civilian manufacturers were no longer prepared to make weapons to Armory standards, which by this time were far more stringent and far more divergent from private practice than in 1861 (see chapters 3 and 7). The department temporized successfully under John T. Thompson, the small arms developer and former ordnance officer, who returned to service and directed the modification of the Enfield rifle being made for British troops by the Winchester and Remington companies. Chambered for the 1906 .30" caliber cartridges but made only partially interchangeable, the privately-produced Model 1917 rifle met American wartime rifle demands. The two firms made nearly 2.2 million weapons, about seven times the wartime output of the two Ordnance Department rifle plants. Springfield failure to provide enough weapons, somewhat similar to the case of the Spanish-American War, contributed to a post-war climate in which the department lost much of its

[150] ARCO 1913, p. 14; ARCO 1894-1912; Aitken, passim; Green et al., pp. 20-21.

earlier control over future weapons designs.[151]

From Limited Funding to Accelerated War Planning, 1919-1941

Following a very brief post-war interlude during which Army and Congressional leaders foresaw a need for large standing forces, isolationism and economic depression created a fifteen-year period of extremely limited military spending. Congress resisted giving the War Department much money when war itself was supposedly being negotiated out of existence during the 1920s, and continued this habit when there was less money to spend after 1930. Despite funding restrictions reminiscent of the period after 1865, the War Department and the Ordnance Department gradually implemented major organizational changes, including establishment of offices responsible for long-term planning of procurement and industrial mobilization. These changes proved to be excellent groundwork for more ambitious war planning after 1935, and helped provide the nation with far more military capability at the start of World War II than was ever previously the case in major conflicts. Until military appropriations rose during the late 1930s, however, implementation of even the best-prepared plans was often severely limited, and at Springfield Armory and other Ordnance Department installations much of this era featured only minimal maintenance of facilities. Expansion of arsenals during World War I made maintenance and repair even more difficult, since subsequent funding cuts basically provided less money to manage more facilities. The Armory's principal achievement in this environment of limited financial resources was successful development of a semi-automatic rifle.[152]

Chief of Ordnance Williams continued to re-organize his department when World War I ended, and during 1919 established the patterns which prevailed at the department's Washington offices for two decades. Following the basic alignments he instituted in 1918 upon return from the European war front, all department operations were divided by weapons or munitions categories, except for three high-level divisions of Design and Manufacture, Maintenance and Distribution, and General Administration. The former two divisions, which managed department facilities, were each responsible for pertinent aspects of all weapons categories and were now distributed more discretely than previously among the field installations. Springfield Armory became part of the Design and

[151] Crozier, pp. 11-21, 56-64; Ezell, "Search," p. 44; Beaver, pp. 77-82; Green et al., pp. 22-7; Weigley, pp. 348-64.

[152] Green et al., pp. 30-31, 42.

Manufacture division, sometimes known as the Manufacturing Service. Raritan Arsenal in New Jersey took over small arms storage tasks formerly associated with the Armory, where responsibilities after 1920 centered on development and improved production of rifles, storage of rifle plans and specifications, and storage of large quantities of gages and machinery used during the war by contractors. Rock Island Arsenal took over the limited federal machine gun production capability from Springfield, and the Armory put the pistol plant in storage, although some experimental work on pistols continued at Springfield during the 1920s along with a capability to make pistol and machine gun barrels. The only new Armory role added during the early post-war period was increased experimentation with all types of machine guns, after an Aircraft Armament unit was transferred to Springfield from Dayton, Ohio.[153]

The Design and Manufacture division, re-named the Industrial Service in 1938, was directly responsible for implementing research and development projects until 1942. Department field installations built all pilot or test designs during this period. The close linkage of research and production continued long-standing Ordnance Department emphasis, and was particularly marked at Springfield Armory and Watervliet Arsenal, the only two post-war manufacturing facilities in the department without basic research laboratories. The Armory's Experimental Department, along with the Chemical Laboratory and Metallurgical Department created during the war, generally dealt with direct applications of testing and research to production problems, with some notable exceptions such as semi-automatic rifle work. Unlike the pre-war era, however, the Ordnance Department no longer maintained exclusive or even predominant control of weapons design and research projects. As part of General Williams' departmental reorganization, a separate Technical Staff acted as a liaison service to all three major divisions, recommending research projects to be undertaken by the Manufacturing Service, and acting as a clearing house for technical information. The principal authority for Technical Staff recommendations, however, came from an Ordnance Committee set up in 1919 to advise the Technical Staff's chief. While the Ordnance Committee, in conjunction with occasional special boards, tested and evaluated new weapons designs in a role similar to that of the earlier Board of Ordnance and Fortification, Williams gave Army "user service" representatives on the committee far greater influence on design decisions than was ever previously the case. Subject usually only to routine approval by the General Staff and the Secretary of War, the Ordnance

[153] Ibid, pp. 33-37; Green, "Springfield Armory," Vol. II, pp. 13-15, 37.

Committee formally approved all new designs and remained the highest effective level of Army ordnance review until 1939, when Chief of Staff Gen. George C. Marshall insisted on General Staff review of all design decisions.[154]

There is evidently no full assessment of the effects of Ordnance Committee decisions on the appropriateness, value, and development of ordnance designs during its 20-year hegemony, but adding new, often conflicting demands to weapons requirements almost certainly slowed down some projects. As we discuss more fully in Chapter 8, varied opinions and directions taken on small arms ammunition contributed to a long series of delays in selection of a semi-automatic rifle. Even the Army Chief of Staff intervened at least once in this process, which occupied nearly thirty-five years of research and testing at the Armory beginning in 1901. It took seventeen years, following the critical arrival at the Armory of machinist and inventor John Garand in 1919, to develop and test a new rifle acceptable to the Army. Production of Garand's brilliant design, the gas-actuated .30” caliber M1 rifle using the 1906 cartridge, required another four and a half years of redesign, production engineering, retooling, and massive facilities preparation at Springfield after design acceptance in 1936. For the first time in United States history, the Army had an up-to-date standard issue shoulder arm--in fact, the most advanced in the world at the time--well into production prior to a major war. Tremendous increases in ordnance funding, which more than doubled between 1935 and 1939, allowed for Armory production of the M1 in time to begin supplying the Army and, later, the Marine Corps by the beginning of American combat in World War II.[155]

Preparation of Springfield Armory for M1 production, as well as maintenance of the Armory during the lean years of 1920-35, remained in control of Armory administrators. The more centralized post-war Ordnance Department administration and planning functions did not really alter the autonomous direction of field installations, and if anything the strength and necessity of such direction increased during this period. Commandants at the Armory and other arsenals retained their traditional combined roles of military commander and industrial manager, with subordinate officers nominally in charge of production, experimental, or other divisions. The commandants had full authority to re-

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[154] Green et al., pp. 33-7; Ezell, "Search," pp. 53-60, and Rifle Controversy, p. 24; ARSA 1918-19, at SANHS.

[155] ARSA 1935-41, at SANHS; Julian S. Hatcher, Hatcher's Book of the Garand, pp. 110-25; Ezell, "Search," pp. 6-7, Rifle Controversy, pp. 29-35; Green, "Springfield Armory," Vol. II, pp. 67-9, 95, 131-32; Johnson and Haven, p. 291; Sharpe, pp. 520-27.

organize their labor and production arrangements, subject to funding restrictions. Unlike earlier years when commandants and some subordinate officers remained at the same facilities for long periods, however, ordnance officers after World War I generally moved to new assignments at least once every four years. Frequent movement was in part to provide greater experience among the very small number of ordnance officers available to manage manufacturing arsenals. This turnover process gave increased importance to the role of longtime civilian employees, some of whom had decades of experience, in sustaining technical and organizational skills.[156]

The Armory commandants' most important job prior to the renewal of funding was retaining a core of trained civilians, a task which led to both cost-saving measures and somewhat innovative means of obtaining projects justifying Armory operations. Through the 1920s, reorganization of physical plant and new manufacturing economies helped stretch limited budgets, even though most traditional Armory production was at a minimal level (see Chapters 5 and 7). To secure more work, Armory managers took on competitive non-military jobs for the first time, meeting industrial demands of other federal agencies. This latter tactic became less effective during the early 1930s as general economic conditions worsened and federal funding diminished even further, and in 1934 the Armory had to lay off many experienced men and reorganize its supervisory force. By 1935, however, availability of Works Project Administration and Public Works Administration funding allowed for overdue maintenance and construction programs, greatly amplified thereafter by Congressional funding of war planning programs.[157]

World War I dramatically revealed an Army largely unprepared to procure its ordnance through national industrial mobilization. There were unprecedented demands for peacetime war planning and explicit recognition of the need to coordinate civilian production. Soon after General Williams' reorganization of the Ordnance Department, the Assistant Secretary of War and the General Staff divided new responsibilities in procurement planning, under the National Defense Act of 1920. To eliminate the competition for civilian facilities which plagued World War I procurement, a planning branch set up by the Assistant Secretary worked with staff departments, such as ordnance, in defining how and where to procure munitions which the government could not produce. Control

[156] Green et al., pp. 36-7, 45-6.

[157] Ibid, pp. 30-31; Green, "Springfield Armory," Vol. II, pp. 23-6, 54.

over what would be procured remained with the staff departments, under General Staff supervision, but there was no longer any question of relying largely on Ordnance Department munitions manufacture during wartime.[158]

Long-term planning for industrial mobilization, and for procurement or production of the most critical armament needed during the initial period of a possible large-scale conflict, began in 1920 but proceeded in a slow, piecemeal manner for the next decade. The civilian-administered ordnance districts of World War I, responsible for coordinating private industrial efforts, were disbanded after the Armistice and were only reestablished in 1922. There were at this time no formal links between the ordnance districts, compiling data on local industrial capabilities, and the federal arsenals with the specifications and expertise needed for private arms production. Comprehensive six year plans for re-armament and related research evolved during Gen. Douglas MacArthur's tenure as Chief of Staff (1930-35), but more realistic planning and actual procurement developed under his successor, Gen. Malin Craig (1935-39). Craig eventually had the advantage of more Congressional funding, but he also chose to reduce research spending, emphasizing instead the procurement of more available weapons sooner rather than more perfect weapons later. Earlier completion of most semi-automatic rifle development allowed that program to proceed unhindered. Beginning in 1935, War Plans sections at the federal arsenals coordinated possible private production with the ordnance districts or directly with some firms.[159]

President Franklin D. Roosevelt's reluctance to concentrate much industrial mobilization power in military hands, during a period of isolationism, continued to limit war planning until 1938, when more overt threats of war in Europe quickly led to dramatic increases in ordnance funds. Ordnance Department allocations for the fiscal year ending June 30, 1939, were some 266 percent higher than those of the preceding year, and as a percentage of the War Department's budget represented an increase for the same period of more than 500 percent. For the first time since World War I, the department could begin actual preparations for private armament manufacture through a series of "educational orders" designed to provide a few firms with experience in meeting ordnance requirements. The first four of these orders, made in 1939, included one to the Winchester

[158] Weigley, pp. 404-8; Green et al., p. 32.

[159] Weigley, p. 404-6, 415; Green et al., pp. 33-7, 47-54.

Repeating Arms Company, in New Haven, Connecticut, for M1 rifles. Although Springfield Armory M1 production was by then underway at increasing speed, the infantry considered the new rifle its premier priority in the rearmament program, requiring assurance of early procurement and delivery. The Armory by this time focused almost exclusively on M1 manufacture, and planned to delete all other production items except barrels for pistols and machine guns; most research there now concerned outstanding M1 fabrication problems. The success of Armory preparation for M1 manufacture, a process underway after 1935, is reflected in the fact that while Winchester continued to make the rifle during World War II, it was the only private plant to do so and the Armory's output was far greater. Despite this concentration of effort, however, the Armory in 1940 became more involved with other armament orders placed with private firms, leasing surplus machine tools stored for two decades. In that year, about three quarters of Ordnance Department allocations went to private industry for complete products, or for materials and components used in manufacture at the arsenals. Both the department and the Armory were thus well-prepared for the unprecedented logistical requirements of World War II.[160]

1942-1968

The most dramatic and obvious break in Springfield Armory history, prior to the 1963 decision to close the Armory, was the shift after World War II from a basic mission of small arms manufacture to one of research, development, pilot production, and technical support of private contractors (Chapter 1). Despite the remarkable contrast between the Armory's wartime performance and its postwar mission, the key to understanding the period ending with the Armory's closing is the transformation of Army ordnance during World War II. Changes in both the Armory and the Department resulted in the dramatically new scope of Ordnance Department responsibility and in the permanent involvement of contractors in Ordnance procurement during that war. There has never been any comprehensive attempt to reconstruct what has happened to American military procurement since 1941, even within one service or department: the Byzantine burgeoning of bureaucracy, the far-flung oceans of classified and unclassified documents, and the complex, often unrecorded arrangements between public and private interests all make for lifetimes of potentially unrequited research. This section offers a brief interpretation of the period.

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[160] Weigley, p. 408, 431-5; Green et al., pp. 31, 36, 41, 59; Green, "Springfield Armory," Vol. II, pp. 85-6. 93, 131.

Until early 1942, the Ordnance Department was one of many Army supply bureaus reporting directly to the Army Chief of Staff. During the upheaval of mobilization after Pearl Harbor, reorganization of the Army included a new Services of Supply command (later the Army Service Forces, ASF) to coordinate all logistical departments or bureaus. Many senior Ordnance Department officers came quickly to resent this additional layer of bureaucracy, which imposed standardized, ASF-wide systems of reporting and organization, and, in their eyes, added few substantive improvements to department results while making numerous unnecessary inspections and requests for statistics. ASF proposals to merge all Army technical services were particularly unwelcome to a department which had operated independently for 130 years.[161] The Ordnance Department regained its more direct connection to the Chief of Staff, along with twenty-eight other bureaus or departments, when the ASF disappeared in the 1946 Army reorganization.[162]

Although the ASF appears to have had little effect on wartime production at Springfield Armory, it probably accelerated the pace of paper reorganizations and re-named departments which mushroom without warning in Armory reports after c1935. One possible, though hitherto unexplored, effect of the ASF may have been an introduction of growing uneasiness between Armory managers and their superiors, who were now not only a much larger Ordnance Department, but several new layers of unfamiliar bureaucracy. After the great demand for M1 rifles eased in 1944, even formal Armory reports began to convey a kind of institutional identity crisis which persisted long after the end of the ASF.[163]

Ironically, wartime strengthening of traditional arsenal autonomy probably exacerbated this problem, by combining great Armory responsibilities with a diminished sense of long-term purpose within the larger organization. Ordnance Department internal structure for procurement and manufacture remained relatively unchanged during the war, despite enormous growth in department personnel and duties. The Washington staff of the department exploded from about 400 in 1940,

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[161] Green et al, The Ordnance Department, pp. 91-5, recounts complaints which, though reserved in manner, are fairly remarkable in an official history.

[162] Weigley, pp. 487-88.

[163] E.g., Green, "Springfield Armory," Vol. II, p. 416.

with 56 career officers, to about 5,000 by June 1942.[164] To achieve unprecedented procurement goals, the department under Chief of Ordnance Lt. Gen. Levin Campbell (chief 1942-46) took several important steps affecting the traditional roles of manufacturing arsenals such as Springfield Armory, within the Industrial Service. Arsenal commanders received greater autonomy and assignments for narrower ranges of products, to better deploy their factories. At the same time, arsenal responsibilities for procurement through contracting were drastically reduced. Springfield had no such responsibilities after June 1942.[165]

It is important to recognize that the variety as well as the quantity of weapons made the Ordnance Department dependent on private procurement. In small arms alone, the weapons needed included more or less familiar rifles, carbines, pistols, and machine guns, and newer items like bazookas, flamethrowers, grenade or rocket launchers, and recoilless rifles.[166] The manufacturing arsenals had traditionally concentrated on production of a narrow range of weapons, although development work had sometimes covered items made by contractors. The Armory had always made small numbers of miscellaneous weapons and parts, including the brief period of pistol manufacture before World War I, and small numbers of machine guns, automatic rifles, and match or .22” cal. versions of the M1903 in the 1920s and 1930s, but production always focused on the standard service shoulder arms. In light of the extensive tooling-up program for the M1, and the need to train thousands of new workers to make that weapon, Armory managers found manufacture of components for other small arms difficult and unproductive. Between June 1942 and June 1943, contractors began manufacture of virtually all items made at Springfield except the M1 and barrels for .50” cal. machine guns; Rock Island Arsenal took over most .30” cal. machine guns. Springfield retained technical responsibility for most of these contracted weapons, along with newer items never made at the Armory such as the M1 carbine developed by Winchester, the M1 rocket launcher, and the M9 flamethrower. In its role as the Army's chief technical center for small arms, Springfield provided manuals, technical assistance, and inspection programs or gages for contractors.[167]

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[164] Green et al., pp. 83, 88.

[165] Ibid, p. 96; Green, "Springfield Armory," Vol. II, pp. 216-20.

[166] Green et al., p. 3.

[167] Green, "Springfield Armory," Vol. II, pp. 216-17.

To work more closely with private contractors, overseen through ordnance district organization, General Campbell formed an advisory staff of prominent businessmen.[168] In small arms, the department came to realize that some contractors could meet mandated specifications without necessarily following Armory practice in all particulars; for weapons never made at Springfield, in fact, there really was no developed Armory practice. One lesson of World War I was that industrial mobilization had to take industrial practice into account. By 1944, it appears that industrial practice was not only an acceptable alternative to methods used at Springfield or other arsenals, but often a preferable alternative to the Ordnance Department or the ASF. Between February and June 1944, the department ordered Springfield's Inspection Department to begin conforming inspection procedures to private industrial practice (see Chapter 3), and the War Planning section to collect data on contractor performance for identification of the "best" industrial systems.[169] Actions such as these made this year one of critical transition at the Armory, as seen below.

Even before the war ended, then, the Ordnance Department was carefully considering more use of commercial practice, or of commercial procurement, or both. Plans for the latter have not, to our knowledge, ever been documented, nor have the early post-war rationales for committing Army small arms procurement to private industry.[170] At a minimum, it seems reasonable to state that the department recognized the futility of developing an arsenal system large enough to handle the size and variety of arms then used by the Army, given the enormous industrial capacity of the United States in 1945. For the American military to grow into its new international, post-war role, a new scale of peacetime procurement was at hand. Perhaps equally important was the fact that American industry, beyond the traditional munitions and firearms manufacturers, had for the first time since the Civil War made money making ordnance. Ordnance procurement had been a very large wartime business, touching all parts of the country, and developing much positive reaction from management and labor, voters and politicians. The military needed public support as well as assured supplies of

[168] Green et al., p. 96.

[169] Green, "Springfield Armory," Vol. II, pp. 239a-40, 418-20.

[170] Edward C. Ezell, perhaps the most assiduous student of post-1945 small arms procurement, has been able to conclude only that "For some reasons as yet unexplained, the Ordnance Department seemed to be unwilling to rely as heavily on the Armory as it had in the past," in The Great Rifle Controversy, p. 76.

more weapons, and commercial procurement quickly became part of a symbiotic relationship. It was no longer politically acceptable for the military to compete with private industry, when industry could rightfully claim a generally solid record of wartime production. The non-military elements of this situation are important for understanding the Armory's story, if they help answer the puzzling question: why stop production at what was perhaps the most prolific rifle factory in the world in 1945, and look for someone else to do the same work?

It was apparent to many people at Springfield Armory in early 1944 that something on that order was likely to happen. Cutbacks in M1 orders began at this time. With the remarkable success of M1 production, summarized in Chapter 1 and given more attention in Chapters 6 and 7, the Armory had almost put itself out of work. Scurrying for things to produce, Armory managers shifted to .50” cal. machine gun barrels, and began cleaning and repair operations for the first time since 1941. Most significantly, they requested work for the Job Shop, once a bulwark of miscellaneous production and innovative machine tool use which closed in late 1943 after the Armory stripped itself of all production but M1s and machine gun barrels. This shop became the core of early planning by Springfield staff for the Armory's post-war role.[171]

Many at the Armory believed that extensive planning for the postwar period was already being done, and employees worried about future Armory directions. Transfers and patterns of assignment of military officers were watched closely by civilian employees, who thought they saw a trend when three of five new officers were attached to the Engineering Department in the first half of 1944. The general consensus was that future activities would emphasize research and development instead of production.[172] This turned out to be a perceptive appraisal. Equally worried, Armory managers established a Control and Special Planning section to formulate post-war plans as the M1 cuts began, in large part to respond to an Ordnance Department request for Armory demobilization plans. Armory planners knew that a return to the program of 1919-20, when storage and experimentation were stressed, would be highly uneconomical given the plant's much larger physical size after the M1 buildup. Instead, they conceived a plan to develop the Job Shop as a pilot production plant for all new small arms, and successfully presented the idea to the Ordnance Department. By mid-1944,

[171] Green, "Springfield Armory," pp. 416, 465-67.

[172] Ibid, pp. 416-417.

the Job Shop was open again, initially to handle some new production orders, but also with a $100,000 allocation for equipping the shop for pilot production.[173] This plan grafted the Armory's existing technical responsibilities for most small arms to its well-established manufacturing abilities, and its existing experimental facilities (Chapter 8).

In part by Ordnance Department mandate, and in part by defensive Armory planning, the Armory's post-war role was defined before the war ended, and was quickly reflected in early post-war Armory activity. Most new production of service weapons ended, and a research and development division (which passed through several name changes) quickly amalgamated disparate testing and development offices.[174] The Armory also regained principal responsibility for small arms procurement within the Ordnance Department, including oversight of contract performance. In 1947, new contracts with private firms addressed plans for private procurement of all major weapons, including the M1, in the event of another war.[175] Even with a somewhat unfamiliar role as a non-manufacturing center for research, development, pilot production, and procurement including technical support, the Armory's future as a major Ordnance Department technical center seemed secure in the late 1940s.

By the early 1960s, Springfield's reputation was poor among many Department of Defense staff, having become ensnared in an extremely complex web of Army and procurement politics, and research and production problems. We review the Armory's post-war research accomplishments at length in Chapter 8. The critical development program for a lightweight rifle, which stimulated much opprobrium by 1961, was sometimes plagued by traditional Armory preference for existing designs and manufacturing methods. More fatal to Springfield's future, though, were desperate bureaucratic struggles for control of Army ordnance, a decided lack of direction in Army small arms research, and a firm Army commitment to private procurement despite a number of contractor failures.[176]

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[173] Ibid, 497-500.

[174] R.J. Malcolm, SAHS, 2 September 1945 - 30 June 1951, SANHS, pp. 104-106.

[175] Ibid, pp. 40-46.

[176] Edward C. Ezell's unpublished "Death of the Arsenal System?" used the broadest range of pertinent documents on this issue likely to be available in the foreseeable future. Our brief account of the Armory's fall follows his work closely.

Ground forces endured some neglect during the 1950s concentration on atomic weapons strategy. Fewer fiscal resources contributed to more competition within the Army for control of missions and personnel. The Ordnance Department, renamed the Ordnance Corps in the 1950 Army Reorganization Act, retained its independent status but found other Army interests eyeing its work hungrily. The Continental Army Command, established in 1955 to direct land forces in the United States, soon gained oversight authority for research and development.[177] Ordnance Corps research efforts at this time retained the generations-old weaknesses of a bias towards production, and often unworkable design wishes by field officers: the attempt to make a lighter rifle with .30" cal. firepower was only the best-known of these contradictions (Chapter 8). In 1957, the Continental Army Command decided to sponsor the SALVO project, in which small arms would fire .22 cal. multi-directional clusters of small projectiles, or flechettes, rather than single cartridges. Promoted at a time when a final decision on the M14 was imminent, SALVO stimulated bureaucratic combat between the Ordnance Corps and the Continental Army Command, and spawned contractor ambitions which competed with Springfield's nearly complete M14 development.[178] In the context of both this competition and the decade of delays in lightweight rifle development, the Ordnance Corps pushed the Armory to put the M14 into pilot production with little production engineering. This rushed production contributed to later contractor failures in making the M14, which in turned earned Springfield the wrath of defense planners.[179]

The same pressures spawning bureaucratic conflict between the Ordnance Corps and other Army commands worked within the corps as well. Springfield lost a particularly critical competition in 1954, when the corps established a new Ordnance Weapons Command (later Army Weapons Command) at Rock Island Arsenal. This command was charged with supervising and coordinating the work of the manufacturing arsenals, and essentially added a layer of bureaucracy without any commensurate expertise. Rock Island immediately took over the mission of national weapons procurement, reducing Springfield's ability to control the quality of contractor work. It was also this command, lacking any small arms development expertise, which ordered the rushed pilot production

[177] Weigley, pp. 528-29.

[178] Ezell, Great Rifle, pp. 163-183.

[179] Ibid, pp. 140-41.

of the M14 at Springfield.[180]

In 1962-63, the Department of Defense reorganized the Army again, part of Secretary of Defense Robert McNamara's drive for efficiency. The Ordnance Corps finally succumbed to a generation of pressure for functional amalgamation of the supply services, and was absorbed into the new Army Materiel Command. The Weapons Command at Rock Island was one of five within this new entity. When Army Chief of Staff, Gen. Earle Wheeler, immediately initiated a series of studies on redundant or ineffective bases in the Materiel Command, Rock Island recommended closing Springfield and absorbing its functions. McNamara, publicly appalled at the handling of the M14, was inclined to agree, and in 1963 announced that the Armory would be closed. When the cost savings claimed by McNamara failed to stand up to analysis by Armory supporters, during a year of review and additional studies, military and civilian supporters of the move to Rock Island simply argued that private industrial capacity to develop and produce new weapons made Springfield unnecessary. McNamara announced a final closing order in November 1964, initiating a phase-out of Armory operations which ended in 1968.[181]

Claims of contractor proficiency and cost-effectiveness in this period were somewhat exaggerated. While the Armory probably did no go far enough in adapting manufacturing methods to practices acceptable to industry, the performance of many firms in major small arms contracts in the 1950s and early 1960s was abysmal. Springfield's residual production capability demonstrated the higher quality of Armory work during fiascos such as private M1 production during the Korean War, even with some Armory problems in re-starting manufacture of the rifle (Chapters 3 and 7). When Springfield replaced failed M1 components for contractors, the costs were charged to Armory overhead--making private performance look far better than it was.[182] Springfield's production of the M14 was also notably better than all private contractors except TRW, which successfully adapted techniques used in a variety of industries.[183]

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[180] Ibid, pp. 141-43; Ezell, "Death..," p. 11.

[181] Ezell, "Death..." It is quite clear from Ezell's material that the studies made of Springfield Armory by the Army were, simply, rigged: the initial assumptions in the two major studies were that the Armory would close.

[182] Ibid.

[183] Walter J. Howe and E.H. Harrison, "Making the M14 Rifle."

In the rush to foster private manufacture and consolidate operations, the Army was never able to replace Springfield Armory's role in providing technical support or supervising research conducted under private contract. Attempts by the Rock Island command to fill the void have generally served only to highlight it.[184] A lack of informed oversight in small arms development remains a problem for American armed forces. Closing Springfield Armory, and dispersing its staff and facilities, has to date proven to be an irreversible step. It is extremely difficult to reconstruct the technical capabilities accumulated at the Armory over a period of 174 years.

B. The Armory's Principal Products

Springfield Armory's manufacturing versatility allowed for a wide range of weapons or weapons components throughout its history, but the overwhelming focus of its production before 1945 was in the standard Army shoulder arms. This section describes the standard Springfield-made weapons, whose increasing complexity stimulated many of the technical and organizational changes reviewed in Chapters 5 through 7.[185] Because of copyright issues in reproduction of useful drawings of the standard weapons, we can append no good weapons illustration to this report. Readers are referred to James Hicks' Notes on United States Ordnance, vol. 1, for illustrations of all weapons discussed here except the U.S. Rifle M14, for which R. Blake Stevens' U.S. Rifle M14 is useful. Administrative and development origins of these weapons appear in Section A, above, and in Chapter 8.

The Flintlock Musket

The first weapon produced at Springfield, now known as the US Model 1795, was a flintlock musket patterned after the French 1763 Charleville which served as the principal arm of the Continental Army. The thirty-year-old design was familiar to the officers and men of the Army in 1794, and served a government lacking the time, resources or administration needed to design a new service musket. It was a large weapon--.69” caliber with a barrel 44.75 inches long--of proven

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[184] Edward C. Ezell, "Patterns in Small Arms Procurement Since 1945: Organization for Development."

[185] Until the Civil War, Harpers Ferry Armory and private contractors made some service shoulder arms not made at Springfield. We do not discuss such other models, which were generally rifles or Hall breechloaders made for special regiments, and which appeared in far fewer numbers than the Springfield arms. Flayderman, Chapter IX, is presently the standard guide to Army shoulder arm models.

performance.

The barrel of the M1795 was an iron tube, closed at the breech end with a threaded plug and drilled with a small touch hole on its side. The inside of the barrel was bored to a smooth, uniform diameter of 0.69 inch, but the outside tapered so that the breech was thicker than the muzzle. The flintlock mechanism, mounted beside the breech, ignited the powder charge in the barrel. Each musket included a steel bayonet for attachment to the muzzle for hand-to-hand combat, and a ramrod for loading the musket. The lock, barrel, and other parts were mounted on the wooden stock, which held them in proper relationship to each other while the bayonet attached to the barrel.

The group of parts called the mountings included three bands which held the barrel in its groove in the stock, three flat springs holding the bands in place, the trigger plate and trigger guard, the side plate, and the butt plate attached to the shoulder end of the stock for its protection. Screws, at that time often called "pins," were used to attach these parts to the stock.

The lock mechanism had a small covered pan for the priming powder located beside the touch hole, a flint mounted in the jaws of the cock, and a battery (sometimes termed the hammer or the modern term, *frizzen*) with a hardened steel face. The striking and scraping action of the flint against the steel produced the sparks which ignited the priming powder. When the trigger was pulled, the cock, impelled by the force of the mainspring, drove its flint against the battery, which was pushed backwards to uncover the pan and permit the sparks to fall into the priming powder.

The lock mechanism contained about 30 separate parts, all of which had to fit or operate smoothly together, and be tough enough to sustain the shocks of repeated firings. These parts were mounted on the lock plate, which held them in proper relation to each other. Cocking the lock compressed the mainspring, which activated the mechanism. Pulling the trigger moved the sear away from the tumbler, allowing the mainspring to rotate the tumbler and cock assembly to accomplish the firing action. If the musketeer allowed the powder to become damp, the touch hole to become clogged, or had forgotten to prime the pan and load the musket with powder, a misfire resulted. Unless cared for properly, the flintlock musket could become an unreliable weapon.

After initial production, there were various small changes made to improve the M1795. Of the approximately 80,000 Springfield flintlock muskets made before 1815, about 15,000 made before 1806 had the bayonet permanently attached, and later removed by shortening the barrels. The M1795 gave way to the M1816, which had a shorter barrel and an improved lock. This was simply one point in the more or less continuous, slow evolution of the weapon. Further changes in the lock parts and mountings led to the model 1840, production of which continued at Springfield until the manufacture of the M1842 percussion muskets began. There were also variants of the basic design made at Springfield to satisfy the special needs of troops in the cavalry and artillery. The first fifty years of Springfield Armory operation, during which almost 475,000 flintlock muskets were made, was a period of remarkably stable weapon design.

The flintlock musket contained many intricate and highly stressed parts. Faults in manufacturing would manifest themselves quickly: a poorly made barrel was liable to burst, and parts in a defective lock to break. Contemporary observers found many of the muskets made at Springfield in the early years to be of inferior quality (Chapters 3 and 7), contributing to an eventual obsession with high quality materials, superior workmanship, and interchangeable manufacture.

The flintlock musket also suffered from inherent defects in principle, the most serious of which were the short effective range (about 60 yards), the need for the musketeer to stand up while loading, and the susceptibility of the priming powder to damp, which would cause misfires. After 1840 a more reliable form of ignition (the percussion cap) was adopted, and the flintlock musket gave way to percussion arms. Rifling later improved the range and accuracy of Army muskets.

Percussion Muskets

Percussion ignition solved the flintlock problem of unreliable firing in damp conditions. Early in the 19th century a Scotsman, Alexander Forsyth, showed that potassium chlorate exploded by a hammer blow could be used to ignite black powder. Joshua Shaw of Philadelphia subsequently designed a small metallic cap to contain the percussion mixture, which made percussion ignition practical for a military weapon. It was adopted by the French in 1822 and the British began conversion of their muskets in 1839. A tenfold reduction in the misfire rate was immediately obtained.

The first U. S. percussion smoothbore musket was the M1842. The pan, flintlock cock, and the battery (the striking steel popularly called *frizzen* today) were no longer required, being replaced by the new percussion hammer and the cone, or nipple, screwed into a projection on the side of the barrel where the touch hole had previously been located. Because the basic lock mechanism is unchanged, conversion of old flintlocks to percussion was practical. The conversion method used at the Springfield Armory was known as the "Belgium plan"; the touch hole was plugged and a cone screwed into the end of the barrel in a position offset from the centerline toward the lock side. The flint ignition parts were removed from the lock, unneeded holes plugged, the strength of the main spring reduced, and a percussion hammer attached.[186] In addition to making 172,000 M1842s, the Springfield Armory converted many older muskets to percussion in the 1840s.

The Percussion Rifle-Musket

The use of a spherical bullet, which is subject to great air resistance in proportion to its weight, was one cause of the short effective range and low accuracy of the smoothbore musket. Another was the poor fit of the ball to the bore of the barrel, allowed to permit easy loading under battle conditions. In 1848, Captain Claude Minié of the French Army developed a pointed bullet with a hollow base containing an expander plug which overcame this problem.[187] Because a non-spherical projectile will tumble end-over-end in flight unless it is spinning about its axis, the Minié bullet required firing from a rifled barrel, which contains spiral grooves to rotate the bullet. Adoption of the Minié system increased the effective range of muzzle-loading small arms from about 60 to about 500 yards. The first rifles made at Springfield were conversions of .69” caliber muskets. The musket barrels were thick enough to be grooved for shallow rifling; a spherical bullet was used and a rear sight added.[188] A better method of converting muskets to rifles was adopted after 1854: a tube was brazed into the musket barrel to reduce the caliber to .58”, allowing use of the same ammunition as that used with newly-made rifles.[189]

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[186] Hicks, Vol. I, p 79; Flayderman, p. 415.

[187] James Burton, Assistant Master Armorer at Harpers Ferry, later discovered that the expander plug is unnecessary; see Charles W. Sawyer, Our Rifles, p. 148; Robert Reilly, United States Military Small Arms, 1816-1865, pp. 25-6.

[188] Sawyer, p. 146.

[189] Ibid, p. 147.

After extensive experiments, outlined in Chapter 8, to determine the best bore, and the form of rifling for the Minié bullet. The Ordnance Department adopted caliber .58", with rifling consisting of three grooves 0.3 inch wide, 0.005 deep at the muzzle, and 0.015 inch deep at the breech with one turn in six feet was adopted.[190] The first musket made at Springfield to these specifications was the US M1855, illustrated in Figure 2.3. Since the long-barrel version of the M1855 was similar to a musket in outside appearance, it was called a "rifle-musket." The accuracy attained with the M1855 rifle-musket was sufficient to hit a target the size of a man on horseback at 600 yards.[191]

The M1855 was the first military arm to include the Maynard primer system. Patented in 1845, the system required extensive Ordnance Department testing and redevelopment before full production began in 1857.[192] A coil of waterproofed paper tape containing pellets of priming compound was stored in a small cavity in the lock plate covered by a hinged door. When the hammer was cocked, the tape was advanced so as to place a fresh pellet over the cone. According to Sawyer, "When all conditions were at their best this automatic primer worked excellently and when first applied it was considered a wide step forward in celerity of fire."[193] The Maynard primer did not prove reliable in service, however, and by 1863 was replaced with a cone first used in 1845. The modified M1855 became first the M1861 and then the M1863, the principal shoulder arm used by Federal troops in the Civil War. The Springfield Armory made about 800,000 of them during the war.

The Breechloading Single-Shot Rifle

Many Civil War riflemen in the heat of battle repeatedly loaded but did not fire their weapons.[194] One reason for this was that the muzzle-loading rifle-musket gave no direct evidence of whether it was loaded or empty. Also, this rifle, like its predecessor the smoothbore musket, could only be loaded by standing riflemen. Both these problems could be obviated by breechloading. The principal technical problems to overcome were creating a gas-tight seal at the breech, and designing a

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[190] Ibid, p. 149; Fuller, pp. 113-15.

[191] Sawyer, p. 151.

[192] Reilly, pp. 21-33.

[193] Sawyer, p. 149.

[194] T.J. Treadwell, Metallic Cartridges Manufactured and Tested at the Frankford Arsenal.

mechanism that would not become inoperative because of fouling by powder residue. Experiments with breechloading had been continuing since the earliest days of firearms and, by the time of the Civil War, there were several alternative designs in use.

The early breechloaders all tended to leak gas when fired. The development of an effective expansive, or metallic, cartridge finally made breech loading practical; the expansion of the cartridge case against the bore of the barrel made an effective gas seal. Many individuals were involved in the development of the metallic cartridge, principally D. B. Wesson (of Smith & Wesson) and B. T. Henry, who developed a metallic cartridge and repeating rifle for the New Haven Arms Company (later, Winchester Repeating Arms).[195] The Army and the Ordnance Department did not participate in the development of any of these new weapons with metallic cartridges before the Civil War, but immediately thereafter department personnel successfully created the center-fire cartridge and machinery to produce it.[196] This type of cartridge was important in a generation of repeating or magazine rifles which, ironically, the Army did not use.

Late in the Civil War, after the tactical power of breechloaders was apparent, Springfield Armory dominated a search for a new design which could convert rifle-muskets into breechloaders. Although an 1865 board of officers examined 65 designs submitted by private inventors and Armory personnel, it selected a design created by Master Armorer Eskin S. Allin in late 1864, on assignment by Commandant A. B. Dyer. The Armory converted 5000 rifles, known as the Model 1865, using a .58” caliber rimfire cartridge which allowed for retention of rifle-musket barrels. Allin's design was far from the best offered, and reasons for its selection are still debated.[197] Dyer became Chief of Ordnance by the time the 1865 board convened, and took a large part in selecting a design initially ordered by him. He claimed the absence of royalty payments by the government to a private designer was a factor in the selection,[198] but Allin obtained a patent on his design shortly before the selection without the knowledge of Ordnance Department. Because of similarities to elements in the

[195] Williamson, Winchester, chapters 2 and 3.

[196] John Milner Associates, pp. 108-12.

[197] Sawyer, p. 168.

[198] Dyer to Stanton, October 21, 1865, RG 156/5.

designs patented by other inventors, the government paid nearly $125,000 in claims when it used Allin's patent, free rights to which Allin belatedly allowed the government.[199] By that time, the department was actively seeking a better design, but it took about seven years and three model changes before a breechloader acceptable to the Army was selected. Springfield designs dominated the selection process.

The Allin system retained the largest number of parts of the Springfield rifle-musket, but if this were a major selection factor, the 1865 board failed to appreciate that some of the 38 new parts required would be difficult to make. Thus, Armory commandant T.T.S. Laidley reported in January 1866 that

> Several of the new pieces are very irregular in shape and extremely difficult to manufacture. The breech block has forty-three different machine operations to complete it. The thumb piece has thirteen cuts on it. The barrel has twenty-eight cuts.[200]

Allin's design required 95 new milling fixtures, 18 drilling jigs, 144 gages, and 240 mills.[201] The "trap-door" mechanism of the original Allin design was screwed onto the Springfield barrel after part of the breech was cut away; a rack was used to activate the extractor. Experience showed the need to change these aspects of the design; a U-shaped spring extractor was introduced in the US M1866 and in the US M1868 the trap-door mechanism was mounted on a separate receiver into which the barrel was screwed. After review by a board of officers, authorized by Congress in 1872 to make a final breechloader selection, a modified version of the Springfield Model 1870 was chosen. The principal changes made were reduction of the caliber to .45 and the substitution of steel for wrought iron in the barrel.[202] After this 1873 decision, the Springfield "Trapdoor" rifle remained in service until replaced by the Krag magazine rifle. Adoption of steel occurred a generation later than was the case for many private arms makers (Chapter 5).

Army selection of a breechloader was an unusually vivid example of Ordnance Department

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[199] Fuller, p. 257.

[200] Hicks, p. 90.

[201] Ibid.

[202] Hicks, p. 96.

commitment to existing designs, even with a multitude of better available choices. The trapdoor rifles were powerful, and popular with many line officers, but only limited post-Civil War funding can adequately explain the tenacious adherence to existing production systems and designs. The Navy, with an admittedly smaller force requiring rifles and no arms factory of its own had a happier experience. In 1869 the Navy decided to convert to a breechloading rifle for use of the Marines and for seamen operating ashore. A board tested many different designs, including the Allin trap-door mechanism. The unanimous preference was for the Remington design based on the 1864 patent of Joseph Ryder, often called the "rolling block action" because of the way the breech block rotated downward for loading. This became the Navy US M1870. The first 10,000 M1870s made at the Springfield Armory had the rear sight in the wrong position and could not be altered without damage to the barrel; they were sold to France (then at war with Germany), and the money so realized used to have Springfield make 12,000 new rifles with the sight correctly placed.[203] According to Sawyer, the Remington-Rider "breech action was strong, thoroughly effective, yet extremely simple. It quickly became world-popular for military arms, and lasted until displaced by the repeater."[204]

The Krag

The first magazine rifle of the U. S. Army was a .30" caliber weapon with a bolt action and an easily-loaded, rotary-type magazine for five cartridges. Based on a foreign design, the American version of the Krag-Jorgensen rifle had little in common with earlier rifles manufactured at Springfield Armory. It was capable of rapid fire from a magazine, and its small caliber cartridge produced a relatively high muzzle velocity of 2,000 feet per second with the new smokeless powder.

The rifle's bolt contained the firing pin body, striker, and mainspring. An extractor was attached, with its hook extending over the face of the bolt. This bolt had only one locking lug, a projection near the forward end which fit into a recess in the receiver when the shooter turned the bolt handle downward. In case the locking lug failed, a slightly-raised guide rib along the body of the bolt would prevent motion to the rear, thus protecting the shooter from the possibility of the bolt flying

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[203] Ibid.

[204] Sawyer, p. 169.

into his face.[205]

Raising the handle began the extraction process, with a curved camming surface on the receiver providing mechanical advantage as the bolt handle moved against it. At the same time, cocking cams cut into the bolt and the cocking piece began the compression of the mainspring. By withdrawing the bolt to the rear, the shooter ejected a fired cartridge case. The bolt picked up a new cartridge from the magazine and slid it into the chamber as the shooter pushed the handle forward. Turning the handle down caused another camming action as the action locked. Philip Sharpe, the best authority on American rifles, claims that "No bolt-action rifle ever produced is as smooth in operation as the Krag."[206]

Springfield Armory made three models of the Krag rifle: the US M1892, M1896, and M1898. There were also Krag carbine models with a shorter barrel. In all these Krags, the bolt and receiver were of plain carbon steel, case-hardened for greater durability, and because there was only one locking lug, which had to withstand the pressure created by firing a cartridge, armory workers took special care in hardening this part of the bolt.[207]

The Krag's rotary magazine could hold up to five of the rimmed, small-caliber cartridges. A soldier simply opened a gate on the right side of the weapon and dropped in loose cartridges. The magazine fed these cartridges, in a rotary path, under the bolt and up to the left side of the receiver for loading in the chamber. A cutoff allowed single-loading, with the contents of the magazine held in reserve. Figures 19 through 22 of the Ordnance Department's diagram of the US Model 1892 show the Krag's ingenious magazine in operation.[208]

This was the first American service rifle with a wood handguard covering the top of the barrel. The barrel could become dangerously hot, particularly during sustained, rapid firing of the new .30"

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[205] Blunt, "The Modern Infantry Rifle." William S. Brophy, The Krag Rifle, contains an original manual of operation. See also Sharpe, The Rifle in America, pp. 102-107.

[206] Sharpe, p. 105; Blunt, pp. 577-580.

[207] Sharpe, pp. 102-105; Brophy, pp. 16-17.

[208] ARCO 1893, Appendix 43, plate III.

caliber cartridges which had metal-jacketed bullets and a hot-burning, early form of smokeless powder. The protection afforded the soldier by this wood part represents a small but noteworthy advance in the human-engineering of American rifles.[209]

In combat, the Krag's round-nosed bullets proved effective despite their small caliber, and the mechanical parts of the rifle functioned very well. The Chief of Ordnance said that reports confirmed the "excellence of the .30" caliber magazine rifle in all respects." It had undergone severe testing in Cuba in 1898; but "notwithstanding rough usage and unusual exposure in a bad climate under circumstances which prevented the exercise of the usual care in preserving the arm, the breech mechanism worked smoothly and there were practically no failures." Scientific American went even further in praise of the rifle's wartime record: "It speaks volumes for the excellent workmanship put into our new rifle that not a single case of failure or even of miss-fire was reported."[210]

Although the Krag did perform good service in the Spanish-American War, it did not measure up to the Spanish bolt-action Mauser rifles, which American officers saw in action and later tested. The Mauser fired a more powerful cartridge of similar caliber and, unlike the Krag, had two locking lugs on its bolt. Its higher-velocity projectile had a longer maximum range than the Krag bullet and was more deadly on impact at comparable ranges because of its greater energy. With only one locking lug, the Krag could not contain the pressures created by a cartridge like that of the Mauser. Some officers were also impressed by the Mauser's capability for rapid loading from a "clip," or metal charger. Soon after the war, the Ordnance Department began a program to develop an improved service cartridge.[211]

The 1903 Springfield

The most famous, and best-loved, rifle made at Springfield Armory was a bolt-action weapon designed primarily at the government facility but incorporating features from the Mauser and Krag rifles. The Spanish-American War exposed American forces to the capabilities of the Spanish version of the bolt action invented by the German Paul Mauser. Ordnance officers were soon

[209] Sharpe, p. 102.

[210] ARCO 1898, p. 13; Scientific American, May 20, 1899, pp. 331.

[211] Clark S. Campbell, The '03 Springfields, p. 1.

studying the Model 1898 (M98) Mauser adopted by the German Army, a model which is still the standard against which all bolt action rifles are judged. In 1900, the US Department of Ordnance asked the Armory to test a new .30” caliber rifle using a Mauser-type bolt as a possible replacement for the Krag. The problems of design were complicated by the department's wish to minimize royalty payments to the Mauser company; Paul Mauser had many U.S. patents on his rifles and their components. The effort to make a new rifle that was similar to the Mauser but still different led to a few weaknesses in the new design; some resulted from retaining elements of the existing Krag design. After a period of experimentation and modification,[212] the Secretary of War ordered the production of 5000 model 1901 rifles for trial. The Armory was still setting up to meet this order in 1902, when the Chief of Ordnance asked for rapid testing of 100 specially-made examples of the rifle. Enthusiastic board evaluations and additional modifications led to the approval of the new weapon and its official adoption as the United States Magazine Rifle, Model of 1903, Caliber .30”.[213]

The new rifle had a bolt designed for safe operation with high velocity cartridges. This was the most important advantage of the Mauser design over that of the Krag. Two locking lugs projected from the forward end of the bolt, which also included a special safety lug designed to come into play only if both locking lugs failed. The Mauser also used two bolt head locking lugs but had a similar safety lug in a different position from that of the M1903. In the early models of the “03” up to 1918, the bolt and the receiver into which it locked were case-hardened carbon steel. Some of these were apparently too brittle, but very few failed. In 1918, the Armory adopted a more effective, double heat-treating process, and in 1927, both the receiver and bolt were changed to nickel steel, a tougher alloy.[214]

Machined into the bolt were extracting and cocking cams, which performed much like cams in the

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[212] An early form had a slot through the receiver bridge for the safety lug, but this tended to warp the received during heat treating.

[213] Stuart Otteson, The Bolt Action: A Design Analysis, pp. 1-32, 35; Campbell, pp. 1-8; Julian S. Hatcher, Hatcher's Notebook, pp. 1-2; Hicks, pp. 110-112; William S. Brophy, The Springfield 1903 Rifles, pp. 2-22. For the history of Mauser rifles, see Ludwig Colson, Mauser Bolt Rifles, and William D. Baker, "Herr Mauser's Deadly Rifle." Baker says the government paid Mauser $200,000 for use of seven of his patents, based on an agreement worked out between government lawyers and Mauser's firm.

[214] Otteson, pp. 34-36; Sharpe, pp. 115-116; TM 9-1270, pp. 20-25.

Krag and Mauser actions. When the shooter unlocked the bolt by raising its handle, the cocking cam drew the firing pin to the rear and compressed the firing pin spring. The extracting cam provided a mechanical advantage as the bolt and its extractor hook pulled the fired cartridge case from the chamber. Camming surfaces on the locking lugs of the “03” bolt worked against shoulders in the receiver to seat the round when the bolt was pressed forward and rotated into a locked position. Thus the action of various cams on the "03" bolt compressed the mainspring, started the extraction process, and seated a new cartridge in the chamber. The close tolerances and excellent surface finishes of the US M1903 bolt and receiver, combined with its powerful camming action, made it very smooth and effective in operation. This helps explain why many experts preferred the M1903 action to the stronger M98 Mauser. Both the M98 and M1903 were "cock on opening" types, with most of the compression of the mainspring taking place as the bolt was opened. However, the M1903 employed a higher percentage of its 90 degree bolt turning for the final locking operation than did the Mauser.[215]

Army designers based the action primarily on that of the Mauser, but the "03" did have a firing pin assembly, striker, mainspring, and safety mechanism similar to those of the earlier Krag. Unlike the Mauser, the Krag and the "03" had a two-part firing pin assembly and a cocking knob. By grasping this cocking piece, which was part of the firing pin rod, the shooter could cock his weapon without operating the bolt, a capability that was useful in case of a misfire. The Mauser could also be cocked without opening the bolt, but only with the use of a cartridge rim as a tool.[216]

The Mauser's single piece firing pin had none of the spongy characteristics associated with the two-piece M1903 assembly. Proponents of the complicated two-piece design believed it made it easy to replace the striker, a simple and separate part which acted directly on the primer of a cartridge in firing. Actually, the design made fracture of either the striker or firing pin rod more likely. In addition, the direct pull trigger of the M1903 was not as good a design as the double draw or double pull Mauser trigger, and was later replaced in most M1903 match rifles.[217]

[215] Hayes, Elements of Ordnance, pp. 626-627; TM 0-1270, pp. 20-29.

[216] Otteson, pp. 37-8, 41-3.

[217] Ibid, pp. 41-3.

Unlike the Krag, the "03" had a single barrel length which satisfied the needs of both the infantry and the cavalry. No longer would the Springfield Armory have to produce both a short barrel for a carbine and a standard barrel for the infantry rifle. Testing had proven that a barrel of only 24 inches was very accurate. The Krag rifle and the first experimental models of the new rifle had 30-inch barrels. The Krag carbine had a 22-inch barrel.[218]

In a dramatic shift from the form of ammunition used in the Krag, the Ordnance Department went from a rimmed to a rimless (cannelured) cartridge with an extracting groove around the base of its case. Mauser ammunition was also rimless. The extractor hook, similar to that in the Mauser, grasped this groove instead of a rim. The ejector in the "03" operated through a thin slot cut in one of the locking lugs and was positioned on the left side of the receiver. It was a departure from Krag and Mauser forms. The M1903 copied the magazine and floor plate of the Mauser. Stacking ammunition in the "single-column vertical feed" magazine beneath the receiver of the new rifle was easy because of the rimless cartridge. The rimmed Krag cartridge, known as the .30”-40, placed limitations on the design of magazines and would not have functioned as well in clips or chargers. Shooters loaded the "03" from metal clips, forcing the rounds down into the magazine.[219]

Radically unlike the Mauser breech design, the M1903 had a cone breech, a deep funnel leading into the chamber. This design, while not quite as strong as the Mauser, had one advantage of great importance to American--but not German --infantry officers: it was outstanding for single loading of cartridges. The Germans had fully accepted magazine loading and intended their troops to use magazines at all times. American officers still insisted on the capability to load single rounds easily, without putting them into the magazine. Following standard American practice, the M1903, like the Krag, had a cutoff mechanism to allow single loading with the magazine held in reserve. The conical breech of the M1903 helped loading by serving as a ramp for single loading. This ramp-like entry also made jamming less likely during combat, even when loading from the magazine. By 1903, even more conservative infantry officers recognized the value of magazine loading, but few would give up the single loading option.[220]

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[218] Sharpe, p. 102; Hicks, p. 112.

[219] Melvin M. Johnson Jr. and Charles T. Haven, Automatic Arms, pp. 50, 116117; Campbell, pp. 1-4.

[220] Otteson, pp. 30-31, 40.

Avant garde ideas are not necessarily better, and one in this period did not win universal approval. Some army officers, including the Chief of Ordnance, felt that the bayonet had become less important in Twentieth Century warfare. The result of their efforts to downplay the bayonet in the design of the new service rifle drew a vigorous response from the former Rough Rider in the White House. The designers of the "03" made the weapon's cleaning rod serve as both a tool and a bayonet (this had been tried previously on an 1884 trap door Springfield rifle). President Theodore Roosevelt, writing in 1905 to the Secretary of War, said that "the ramrod bayonet (is) about as poor an invention as I ever saw." This particular invention convinced him that it was unwise "to trust too much to theory." The Ordnance Department temporarily stopped production of the rifle, which had already been issued to the troops. The department then adopted a knife bayonet and modified existing rifles to accept it.[221]

Further modification was soon necessary. In 1906, the Ordnance Department adopted a new cartridge for the service rifle, an action which forced the rechambering of all model 1903 rifles made up to that time. The original 1903 cartridge had a 220 grain, jacketed, round-nosed bullet like that of the Krag, but its muzzle velocity had been raised from the 2,000 feet per second of the Krag to a new level of 2,300 feet per second. Unfortunately, the nitroglycerine powder of that cartridge damaged barrels in fewer than 1,000 rounds, and the Army was forced to drop the muzzle velocity back to 2,000 feet per second. A new nitrocellulose powder in 1906 solved the barrel problem. At the same time, the Army adopted a pointed bullet known as a *spitzer* type, a 1904 German development. The French and the Germans had recently chosen pointed bullets after achieving excellent shooting characteristics with the lighter rounds at higher velocities. A 1906 American cartridge with a 150 grain pointed bullet and a muzzle velocity of 2,700 feet per second became the standard issue. The Springfield Armory recalled model 1903 rifles, shortened their barrels slightly and altered their chambers to fit the shorter neck of the new cartridge case.[222]

The 1903 Springfield rifle underwent numerous minor and some major modifications during the

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[221] Campbell, pp. 10-11; Brophy, p. 5; Hatcher, p. 2.

[222] Sharpe, pp. 114-115; Campbell, pp. 12-15; Flayderman, p. 476.

course of its production by Springfield Armory, Rock Island Arsenal, Remington Arms Co., and L. C. Smith-Corona Typewriters, Inc. Some of these changes have already been mentioned above. The published literature on this weapon is unusually rich and provides a wealth of details for the collector or the specialist. TM 9-1270, a 1944 War Department Technical Manual on ordnance maintenance of the M1903, M1903A1, M1903A3, and M1904A4, describes the basic models in use up to and during World War II. Rock Island Arsenal made the M1903 from 1904 to 1919. Early in World War II, Remington made modified versions of the M1903 and M1903A1, and in 1943 and 1944, the firm produced both the M1903A3 and the M1903A4. Smith-Corona made the M1903A3 in 1943 and 1944. The reader should refer to some of the references cited earlier for further information; this report can only cover the most important changes to the weapons made at Springfield Armory.[223]

Springfield made few complete rifles of standard form after WWI, but continued to make parts for the M1903 and to produce special versions of the weapon, including National Match rifles. In 1928 the Ordnance Department replaced the straight grip stock of the original rifle with a stock that had a pistol grip. The modified rifle became the model 1903A1, for “alteration one”. Alteration two was used inside tank gun barrels for shooting practice. The last "03" receiver made at the Armory was number 1,532,878, completed in 1939. The two private contractors mentioned above made the M1903A3, a simplified and relatively inexpensive wartime model with a new peep sight. In July, 1942, Remington had begun to use metal stampings as replacements for some "03" parts that had previously been forged and carefully machined. Production of the M1903A3 (and the M1903A4, a sniper rifle with scope) depended heavily on stamped parts, including the follower, butt plate, trigger guard assembly, bayonet lug, butt swivel, stacking swivel, and barrel guard band.[224]

The 1903 Springfield rifles made at Springfield Armory have a reputation for superb design and construction. Philip Sharpe does not hesitate to express his admiration for this weapon: "The Springfield is probably the most accurate military rifle in the world. It is certainly the finest and most precision-built piece of machinery any military organization has ever produced." He is less generous in commenting on the World War II version of this rifle, which was made outside the

[223] Sharpe, pp. 545-552.

[224] Ibid.; TM 9-1270, pp. 9-14; Hatcher, pp. 6-7.

Armory and with different standards of production: "The use of stamped sheet parts and crude manufacture never has appealed to the American Rifleman." He finds little to like in "the ‘tin can' version," but one must consider that the manufacture of this rifle required fewer skilled men, was less expensive, and took less time. Sharpe admits that it was a "good rifle--but not as good as that which made it the standard bolt action among rifle lovers of America."[225]

The M1 Garand

As discussed in the section on Garand's contribution in Chapter 8, the M1 rifle operated with a system known as "gas actuation," or more precisely, "impinging gas actuation." This system used gas pressure directed from the bore of the barrel during firing to operate the breech mechanism. The bolt of this mechanism was a relatively simple affair. It needed no extracting cam, because there was plenty of force to withdraw the fired cartridge. It needed no special cocking cam, because there was no firing pin spring. Garand kept his bolt short, only as long as the cartridge, and thus was able to use a very compact receiver.[226]

The M1, and the "03" before it, had a Mauser-type bolt, defined as a rotating bolt with locking lugs. Unlike the Mauser, the Krag, or the "03," the M1 firing pin was not propelled by a spring within the bolt assembly, but was instead struck by the hammer from the trigger housing assembly, which also contained the hammer spring, sear, trigger, and safety. The M1 firing pin fit in a hole running through the bolt. It had an L-shaped tang at the rear to prevent it from firing unless the bolt was fully locked. Because of the alignment of a special slot in a bridge across the receiver, the tang could not go forward until the rotation of the bolt was completed.[227]

When the shooter squeezed the trigger, he released the hammer, which then struck the firing pin. The resulting explosion of the primer and propellant sent the bullet on its way down the rifled barrel and built up high gas pressure behind it. In 1940, Garand improved the operation of his gas system and the overall design of his rifle by putting a gas port in the barrel, thus dispensing with the previous sleeve and port in front of the muzzle. As the bullet passed the new port near the tip of the

[225] Sharpe, p. 552.

[226] Johnson and Haven, pp. 86-88, 96, 104.

[227] For a detailed description of the M1 and a wide range of excellent drawings of the rifle, see SA-ITM-S200.

barrel, gas entered the gas cylinder, driving the operating rod to the rear. The action of the operating rod replaced the manual operation that had unlocked previous rotating bolt actions. A camming recess in the rod was in engagement with a projection on the bolt. As the rod moved to the rear, the shape of this recess forced the bolt to rotate, unlocking the two lugs of the bolt from the receiver. Further motion of the operating rod withdrew the bolt and the empty cartridge case. The extractor held the case until the ejector went into action. Both were components of the bolt assembly. A small spring assisted the ejector in throwing the case clear of the receiver.[228]

Moving back with the operating rod, the bolt passed over the hammer, camming it down against the pressure of the hammer spring. After its rearward motion, the bolt reversed direction and came forward driven by the operating rod and the now compressed operating rod spring. The bolt stripped the top cartridge from the M1's clip and seated it in the chamber. Again the recess in the operating rod acted as a cam, rotating the bolt and its two lugs into locked position in recesses in the receiver. The rifle was now loaded with a fresh cartridge.[229]

If the shooter did not release the trigger immediately after squeezing it, the sear caught the rear hammer hooks, holding the hammer until the trigger moved forward. Releasing the trigger disengaged the sear, engaged the trigger lugs with the hammer, and prepared the weapon to fire again. The M1 was thus semiautomatic: it required a separate trigger squeeze and release for each shot.[230]

When the last cartridge in a clip was expended, a catch held the operating rod back and left the receiver open. A clip ejector then pushed the empty clip up and out (the clip, described in a previous section, was a disposable metal stamping designed to hold eight cartridges in a staggered vertical column). The rifle was now ready for a new clip of ammunition which the shooter inserted into the open receiver from above. He used his thumb to press the clip down until the clip latch engaged. Then he released the operating rod to close the breech. Soldiers could sustain a much higher rate of fire with the M1 than they could with the "03" because of the M1's semi-automatic operation and its

[228] Johnson and Haven, pp. 66, 291; Sharpe, pp. 520-521; and SA-ITM-S200, pp. 105-107.

[229] U.S., Department of the Army, SA-ITM-S200, pp. 105-109.

[230] SA-ITM-S200, pp. 108-109, 113.

rapid clip-loading. Captain Melvin Johnson, the designer of a competing semi-automatic rifle, credits the M1 with "double the fire power of a Springfield 1903."[231]

The M14

The M14 rifle has much in common with the M1, from which it was derived by a lengthy process of experimentation and "product improvement." Many parts are interchangeable, and the unmistakable imprint of John Garand's genius is on both weapons. Although the evolution of the M14 made it a different weapon than his semi-automatic M1 or even his experimental, selective-fire T20E2, Garand's design concepts shaped most of its final form.

There are significant ways in which the M14 differs from the M1. Although both rifles will fire semi-automatically, only the M14 can be equipped with a selector switch that allows it to fire in a fully-automatic mode. The bolt of the M14 has a roller on its camming lug which eliminates much of the friction produced by the earlier bolt. The M14 holds twenty rounds in its detachable magazine, far more than the eight rounds of an M1 clip. The ammunition for each rifle has similar ballistic properties, with almost identical projectiles and muzzle velocities, but the NATO 7.62 mm cartridge of the M14 is slightly lighter, shorter, and more compact. With a shorter cartridge, the M14 can also have a shorter receiver. The two weapons use combustion gases from their cartridges to operate their breech mechanisms, but the M14 has a gas cutoff system, while the M1 has a direct impingement gas system. This incorporation of a cutoff in the M14 to allow expansive working of the high-pressure gas was a clear departure from Garand's preferred designs for automatic rifles.[232]

The piston of the M14 gas system is nothing like that in the M1. It is not part of the operating rod, but it contacts the rod and starts it moving. That end of the piston which is enclosed in the gas cylinder is open. A gas port in the barrel, approximately eight inches from the muzzle, lets gas into the piston through a small hole in its the cylindrical sidewall. As pressure builds within the hollow piston and pushes against the fixed cylinder plug, the piston is set in motion. This rearward movement of the piston "cuts off" the entry of high pressure gas from the barrel by ending the

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[231] Johnson and Haven, p. 64-66; SA-ITM-S200, p. 106.

[232] Ezell, The Great Rifle Controversy, pp. 135-136, 145-147; R. Blake Stevens, U.S. Rifle M14 From John Garand to the M21, pp. 12, 179-180, 183.

alignment of the barrel port and piston entry hole. The body of the piston passes under the port, thus acting as a cutoff valve. Expanding gas provides a smooth but powerful force to operate the breech mechanism.[233]

The cutoff and expansion system increases the "dwell time," the critical interval between the firing of the projectile and the unlocking of the bolt. Dwell time is an important consideration in the design of high-powered automatic firearms for safety reasons and because it can reduce the effort needed for extracting a fired cartridge. The operating rods of the M1 and the M14 move short distances before their camming grooves begin to force the rotation of the bolts, but the more progressive action of the M14's expanding gas system allows an additional fraction of a second for residual pressures in the chamber to drop. The longer dwell time does not, however, increase the overall cycle period of the breech mechanism. In full automatic mode, the M14 operates at an impressive cyclic rate of 715 rounds per minute.[234] The breech mechanism is very similar to that of the M1 except for the above-mentioned roller on the camming lug. This roller rides in the camming groove of the operating rod with relatively little friction and eliminates the "freezing" that halted the operation of many M1 rifles, if rain washed away the lubricant on their camming lug. In 1943, Garand had suggested this type of roller as an improvement for his original M1 turn-bolt action.[235]

Garand seems to have had little difficulty converting his basic M1 breech mechanism to allow selection of either semi- or fully-automatic firing. The trick was in controlling the operation of the sear, a part which catches the hammer of the M1 and holds it back until the trigger hooks grab it. In the M1, the trigger must be squeezed again for each shot, with the trigger hooks releasing the

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[233] Stevens, pp. 179-181, 318, provides a brief description and diagrams. For details of construction and operation, see U.S., Department of the Army, TM 9-1005-223-20, 19 May 1967, and TM 9-1005-223-12, January, 1963. Author Malone is grateful to Richard Harkins of the Springfield Armory National Historical Site for providing a wealth of technical information on this rifle. He also owes a debt to his Marine Corps weapons instructors of 1964 and 1965, who once taught him how the M14 worked, how to use it in combat, and how to take care of it.

[234] Stevens, p. 186, and Johnson and Haven, pp. 86, 92. Stevens reproduces part of an R&D report, SA-TR11-2610, 2 August 1954, which shows that gas expansion resulted in 70% of the dwell time of gas impingement in tested T44 models. Some of this had to do with longer dwell travel in the rifle with impingement, but most was due to the expansion system. The authors of the report noted the "smaller extraction effort with the gas expansion system," but did not find a significant advantage of one system's extraction effort with the gas expansion system" over the other. Lt. Col. Roy Rayle, chief of R&D at the Armory in 1954, later explained that the longer dwell time (and reduced peak pressure in the gas cylinder) gave the advantage to the more expensive gas cutoff system.

[235] Stevens, pp. 13, 15; U.S., Department of the Army, TM 9-1005-223-12, January, 1963, pp. 39-40.

hammer. In 1944, Garand produced a connector assembly that could link the movement of the operating rod to the action of the sear, causing the sear to release the hammer automatically after each shot. In fully-automatic mode, if the shooter squeezed and then held the trigger back, it would not catch the hammer, and firing would be controlled by the sear's automatic catching and releasing of the hammer. The sear had to hold the hammer briefly to allow the bolt to lock fully and to prevent "slam firing" that might damage the breech. With further development, Garand's connector assembly became the basis for the selective operation of the M14.[236]

The M14 can be fitted with a selector switch which allows the shooter to select fully-automatic firing. If that switch is not installed in the rifle, then the connecting assembly does not affect the operation of the sear, and the M14 works just like the M1. To fire his M14 as a fully-automatic weapon, the shooter must turn the selector switch, which rotates the eccentric selector shaft and repositions a component known as the sear release. This puts the sear release in position to act on the sear at the proper instant of the firing cycle.[237] The shooter then squeezes the trigger, and the firing cycle proceeds. The trigger group is almost identical with the M1, except for the sear. The basic action of the hammer, firing pin, bolt, and locking lugs has already been described for the M1. Gas venting from the barrel works in the expansion system to drive the operating rod to the rear. A hook on the connecting assembly now disengages from a notch in the operating rod, and the spring driven movement of the selector mechanism causes the sear release to rotate away from the sear. When the hammer is driven back and down by the movement of the bolt in the cocking process, the sear is free to grab the hammer. As the operating rod, powered by its own spring, moves forward in the counter-recoil phase of the firing cycle, the bolt rotates into locked position. The operating rod continues forward and engages the hook on the connector assembly, moving it forward. A stud on the sear release fits through an opening on the other end of the connecting assembly. This forward motion of the connecting assembly thus causes the sear release to rotate and to press against the sear, disengaging it from the hammer. The hammer is free to strike the firing pin as long as the trigger is held back. The bolt must, however, be fully locked or the pin will be stopped at the

[236] TM 9-1005-223-12, January, 1963, pp. 19-20, 33, 37-39. Stevens, pp. 36-38, reproduces TB 9X-115, which provides a detailed explanation of the selector mechanism and connecting assembly operation on Garand's 1945 T20E2. Richard Harkins of the National Park Service added information based on his intensive study of the M14.

[237] TB 9X-115, June, 1945, pp. 5-7, in Stevens, pp. 35-38; U.S., Department of the Army, TM 9-1005-223-12, January, 1963, pp. 19-20, 44.

receiver bridge before it can strike the cartridge. If, at any time during fully-automatic fire, the shooter releases the trigger, its trigger lugs act as a secondary sear and catch the hammer to stop the firing. The sear release cannot prevent the trigger lugs from stopping the hammer; only holding back the trigger keeps them away from the hammer and allows the rifle to continue firing automatically.[238]

The automatic firing is, of course, limited to the twenty round capacity of the magazine. A spring-driven follower in the magazine feeds rounds upward in a staggered column, and the bolt strips one off each time it comes forward in counter-recoil. The follower holds the bolt back in an open position after the ejection of the last cartridge case. Replacing magazines is a rapid operation when performed by an experienced shooter. There is a danger of overheating the barrel in sustained fully-automatic fire.[239]

ABBREVIATIONS IN NOTES

ARCO	U.S., Ordnance Department, Annual Report of the Chief of Ordnance to the Secretary of War for the Fiscal Year Ended June 30, ----.
ARSA	Annual Report of Operations at the Springfield Armory. Titles vary, and reports appear in different archival sources, as noted.
RG156/	Record Group 156, Records of the Office of the Chief of Ordnance, National Archives. Record entry number follows slash.
SAHS	Springfield Armory Historical Summary for the Period ----, on file at Springfield Armory National Historic Site. These are semi-annual or annual reports covering the years 1951-1965.
SANHS	Springfield Armory National Historic Site. This refers to material held by the National Park Service at Springfield.
SFSA	Statement of Fabrications, Other Work Done..at National Armory, Springfield, Mass. Titles vary. These records, in RG 156/21, appear to be the only available summaries of annual operations c1865-93.

[238] TB-9X-115, pp. 5-7, in Stevens, pp. 35-38, and see also Stevens, pp. 180, 200, 202; U.S., Department of the Army, TM 9-1005-223-12, pp. 14, 19-20, 37-39.

[239] U.S., Department of the Army, TM-9-1005-223-12, January, 1963, pp. 14020; Stevens, pp. 188-189, 323, 325.

Chapter 3

GAGES, STANDARDS, AND INTERCHANGEABLE MANUFACTURE

Until the end of World War II, Springfield Armory's primary mission was production of small arms which met the Army's military needs as well as standards of interchangeability and uniformity. Design of small arms acceptable to the Ordnance Department often involved prolonged periods of development, and produced increasingly complex weapons, as we discussed in Chapter 2. Army weapons design was episodic, and required consideration of performance and field conditions as well as uniformity. By contrast, and although redefined over time, the demand for uniformity remained a constant of Armory manufacture after 1815. This demand had important effects on weapons design, and became the prime mover in the growth of "armory practice" at Springfield. Virtually every development in the Armory's physical plant, management of labor, procurement of materials, and manufacturing processes from 1815 to 1945 hinged on interchangeability and uniformity, as we will see in Chapters 4 through 7, even if funding and military crises often determined the pace of development. In this chapter, we discuss Ordnance Department and Armory definitions of interchangeability and uniformity, and the evolution of gaging, inspection, and testing systems used to meet these standards.

A. Defining and Achieving an Ideal

Problems of Definition

Army ordnance uniformity has usually been in the eyes of officers and senior mechanics. Our study of the Springfield Armory's principal products and manufacturing methods suggests that small arms uniformity was an ideal with many meanings within the Army. The concept changed through time at Springfield, as development of measuring systems and changes in manufacturing materials created dissonance in the perception of uniformity. We review some of these changes below. At any given time, uniformity or interchangeability also had a variety of connotations to Armory personnel, other Ordnance Department officers, and Army line officers. There were probably no standard, mutually agreed-upon meanings among these groups, at least until after World War II. This last problem, along with lack of documentation, often makes definition of uniformity difficult, even for specific periods at the Armory. For Ordnance Department personnel, small arms perceived as

interchangeable upon manufacture might not always meet gaging criteria, depending on inspection methods. Similarly, two weapons apparently both meeting gaging criteria might not have identical physical properties, depending on testing methods. For Army small arms users, weapons perceived as interchangeable upon manufacture might not remain so after field use.

During the first half of the 19th century, uniformity to many Ordnance officers like Decius Wadsworth probably meant dimensional uniformity, which for small arms meant interchangeability of component parts. In this ideal, parts taken from any weapon would fit into, and function properly in, any other weapon of the same model. The nature and closeness of this fit gradually changed as manufacturing and gaging methods improved. At one time, it meant that the parts of gun locks were sufficiently uniform that they could be hardened before being fitted into the individual locks, final adjustments for smooth operation being made during assembly after hardening. Later it meant that rifles could be assembled from parts selected individually from large batches of parts to achieve a good fit and smooth action. This is known as "selective assembly." Finally, it could mean that parts were interchangeable without qualification. Interchangeable manufacture does not necessarily mean wholly machine-made parts, and we present evidence in chapters 6 and 7 for at least some hand work on most Springfield Armory products until production of the M1 rifle. We should also note that while Armory production stressed interchangeability between complete weapons, not all interchangeable manufacture followed this course. As we will show in chapter 9, some private industries made only interchangeable subassemblies or working groups of components.

We deal here primarily with interchangeability as a manufacturing objective. Armory managers recognized soon after 1815 that interchangeable manufacture allowed for more quality control, through more complex division of labor and more discrete definition of weapons components. There were, however, other factors of great importance in promoting interchangeability, especially arguments from ordnance and line officers that interchangeability would facilitate repair of arms in the field, and lead to greater economy of manufacture. In this set of ideals, broken parts could be replaced and the weapon returned to service without the aid of a gunsmith to fit or adjust the replacement parts.[240] Decius Wadsworth and George Bomford avidly pursued uniformity and, by

[240] Merritt R. Smith, "Army Ordnance and the 'American system' of manufacturing, 1815-1861," pp. 44-6, and Harpers Ferry Armory and the New Technology, pp. 106-7. The field repair question is the most frequently cited but least well-

the end of Bomford's tenure as Chief of Ordnance, the national armories and some private arms makers had achieved more or less complete dimensional interchangeability of shoulder arms. At least in the early years of the 20th century, some officers also believed that interchangeability would enable an infantryman to repair his rifle in combat with parts salvaged from the arms of fallen comrades.[241] Until the Civil War, interchangeable small arms did not lead to less expensive weapons than could be made under contract.[242] Interchangeability apparently had little to do with field repairs, and probably had nothing to do with repairs made under fire. There have been persistent, fundamental problems in making field repairs to used arms throughout American military history, and Ordnance Department arsenals and armories repaired most small arms until after World War I.[243]

Interchangeable manufacture, although usually paramount in Armory small arms production, was only one aspect of uniformity, even for some early Army Ordnance personnel. The military has usually insisted that an acceptable part for a musket or rifle meet three general requirements. First, the part must be the right size and shape, within established limits of dimensional variation that should be, but are not always, dependent on the particular function of the part. Second, where visible or in contact with other parts, it must have an appropriate surface finish, with standards often determined by functional requirements, aesthetic judgments, or a combination of both. Finally, it must possess the strength and durability to perform its function for the projected "life" of the component, which may sometimes be less than the useful life of the weapon as a whole. With this final requirement, uniformity was linked to consideration of the chemical and physical properties of both raw materials and finished components, and became important long before metallurgy or the study of the strength of materials had become sophisticated fields of investigation in industrial research laboratories. Conformance of muskets to subjective criteria of fit with pattern arms actually

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documented component of Army ordnance uniformity policy.

[241] Frederick Colvin, Sixty Years With Men and Machines, pp. 191-2.

[242] Although we do not deal with Armory costs in any detail, it seems clear that the flowering of "Armory practice" was expensive relative to most private industry; see Felicia J. Deyrup, Arms Makers of the Connecticut Valley, pp. 131-2 and Table 1, Appendix B. This fact is of some importance in our assessment of Armory influence in Chapter 9. Smith claims that Bomford was more interested in manufacturing advances than in cost savings, but used potential economy as an appropriation-raising argument with Congress (Harpers Ferry, p. 120); this theme remains under-documented in early Ordnance Department history.

[243] Constance M. Green et al., The Ordnance Department, pp. 19-20.

preceded demands for interchangeability, as did tests of musket barrel strength with proof charges. When metallurgical requirements of higher velocity ammunition led to changes in rifle components in the late 19th century, the Ordnance Department devoted increasing attention to testing physical properties.

Origins of Ordnance Department Enthusiasm for Uniformity

The enthusiasm of American ordnance officers for the use of interchangeable parts in small arms grew from the work of French engineers, scientists, and army officers in the late 18th century, as part of a revolution in standardized artillery equipment manufacture led by Inspector General Jean-Baptiste de Gribeauval.[244] Encouraged by these developments, Honoré Blanc developed methods at the St. Etienne armory for making musket locks with interchangeable parts.[245] Thomas Jefferson sent an account of Blanc's work to the United States in 1785, and in 1789 he obtained a set of sample French muskets made by Blanc's methods.[246] Although the French and American war departments initially ignored the possibility of making such arms, French officers serving in the United States Army--of whom Anne Louis de Tousard was the most influential--remained strong, vocal advocates of uniformity and interchangeability in ordnance. Their influence, and the obvious need to establish some measure of uniformity in the disparate collection of artillery held by the Army, led Secretary of War James McHenry in 1798 to establish uniformity as a goal for new American cannon. Eli Whitney helped promote the notion of uniformity among all ordnance classes, and won a musket contract which allowed him to maintain the Whitney Armory in New Haven, Connecticut. Neither he nor any other American achieved full interchangeability in muskets during his lifetime, however.[247]

Blanc's example probably inspired the earliest attempt to introduce standardized pattern weapons and interchangeable parts to American small arms manufacture, made by Commissary-General of

[244] Smith, "Army Ordnance," pp. 44-50; David A. Hounshell, From the American System to Mass Production, pp. 25-28.

[245] William F. Durfee, "The First Systematic Attempt at Interchangeability in Firearms."

[246] Edwin A. Battison, "Eli Whitney and the Milling Machine."

[247] Edward C. Ezell, "The Development of Artillery for the United States Land Service before 1861," pp. 64-66, 79-86, 90-95.

Purchases Callender Irvine during the War of 1812. Irvine's authority conflicted somewhat with that of the Ordnance Department, as we saw in chapter 2. His pursuit of some kind of interchangeability with new models may be an early sign of the burgeoning technical ideal pursued by his sometime rivals at the Ordnance Department, but the reactions of contractors and federal arms makers to his wartime production demands suggest that his motives were at best mixed. Although his fierce promotion of models for a new musket and a new pistol may reflect a sincere attempt to improve the quality of contract arms,[248] it is at least as likely that these plans represented both an attempt to gain complete control over production at the national armories, and a private interest in a new standard to be used for all government procurement. Imposing dramatic new technical requirements during wartime, apparently with no preparation for production other than providing pattern arms, was at best quixotic.

Irvine commissioned both models in 1812 from accomplished gunmaker Marine T. Wickham, the Master Armorer at Harpers Ferry who became Irvine's chief inspector of contract arms. By early 1813, Irvine secured approval of both models by the Secretary of War, and added control of unfinished pre-war small arms contracts to his previous authority over new wartime procurement.[249] He then attempted to demand the new models in all contracts. He is perhaps best known for his battle with Eli Whitney over the latter’s successful insistence on the terms of an 1812 musket contract. Whitney openly sneered at the high costs of attempting a model demanding such exactitude as Irvine's. Wadsworth, in charge of the Ordnance Department, and Springfield Armory Superintendent Benjamin Prescott both pointed out numerous design flaws in the new model musket relative to the standard model based on French prototypes. Wartime problems at the national armories, exacerbated at least in Springfield by the demands for repairs by Irvine's office or the Secretary of War, limited production of the Wickham musket to pattern pieces and a small number of others before Ordnance Department officers evidently succeeded in halting production in 1815 or 1816; contractors probably made some of these pieces as well.[250]

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[248] Edwin A. Battison, "The Evolution of Interchangeable Manufacture and its Dissemination.”

[249] George D. Moller, "Early American Pattern Muskets."

[250] James E. Hicks, Notes on United States Ordnance, Volume I, p.41; Deyrup, Arms Makers, pp. 60-2; James A. Huston, The Sinews of War, p. 106; Smith, Harpers Ferry, p. 59; Wadsworth to Monroe, February 4, 1813, and to Armstrong, June 6, 1814, RG 156/5; Prescott to Monroe, February 4, 1815, RG 156/21. Wadsworth insisted on the proven

Irvine's models, and his often acrimonious campaigns to remove or subdue his opponents, had several important effects on later small arms development. The model design flaws, and the at best uneven improvements in arms procurement made by Irvine, contributed to some discrediting of his office. Decius Wadsworth used Irvine's reverses to help secure Ordnance Department control over all small arms procurement after the war. When that department attempted to introduce interchangeable manufacture in small arms, it did so rather cautiously, in part reacting to Irvine's precipitous insistence on making the most difficult musket components identical. Prescott's complaint about the Wickham musket anticipated some of the manufacturing problems encountered during the next three decades:

> "...what constitutes the greatest difference [between the earlier models and Wickham's] is the ridiculous idea of making the component parts of the lock so perfect as to fit any other, until materials can be found to make the tools, etc., that will not wear by constant use it cannot be done."[251]

Armsmaker Simeon North tried making interchangeable pistols in Middletown, Connecticut, under an 1813 contract with Irvine, stimulating Ordnance Department thinking about making uniform locks and other parts.[252] The extent of North's success is unclear, as noted below, and this earliest attempt to make American interchangeable military small arms was probably somewhat daunting: the amount of handwork required in a relatively unmechanized era made efficient, large-scale production almost impossible. Although he concentrated on locks, this critical component was the last in military small arms to be captured by pursuers of interchangeability. More pressing production problems, and the need to develop mechanical and measuring systems, occupied

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superiority of the French musket used in the American Revolution and then serving as a model for American military production, noting that the Irvine model was heavier, had a poorer center of gravity, and replaced the socket bayonet with a screw-retained blade; Prescott noted in addition the expensive squaring of the barrel breech. There remains some confusion about the nature of the Wickham models, and even more about their actual production. Same sources identify Wickham's shoulder arm as a rifle; see Norm Flayderman, Flayderman's Guide to Antique American Firearms, 3rd ed., pp. 434-36.

[251] Prescott to Monroe, op. cit.

[252] North evidently delivered at least several hundred pistols under this contract for 20,000, which was later revised to about 1150; see Flayderman, p. 288, and Battison, "Evolution." The origin of this effort was Irvine's demand, not North's, and recent suggestion that the contract reflected War Department enthusiasm for uniform production conflates the often opposed interests of the Ordnance Department and the Commissary-General of Purchases; cf. David A. Hounshell, From the American System to Mass Production, pp. 28-9.

Ordnance Department attention for several decades.

Assertions in 19th century documents about attainment of interchangeable small arms manufacture should be treated with caution. Careful documentary study or tests on extant weapons have already shown some of these assertions to be inaccurate. For example, there is no primary source for the famous story of how Eli Whitney assembled ten musket locks before the Secretary of War by selecting indiscriminately from a pile of lock parts.[253] Similarly Whitney lock parts tested in one arms collection were not interchangeable[254] Different meanings given to the term "interchangeability" is another problem, as discussed above. The only documentary evidence of Simeon North's success under his 1813 pistol contract is the statement:

> “...he has made an improvement in the lock by fitting every part to the same lock which insures a more rigid uniformity than they have hitherto known.”[255]

This statement tells us nothing about how good a fit was achieved among the different lock parts, or how well locks functioned when made from randomly-selected parts. Some descriptions of interchangeability tests are ambiguous: the 1827 Carrington Committee report on Hall's rifle works states that the committee's tests found Hall rifle stocks interchangeable, but only implies that metal parts were interchangeable among different rifles.[256] In this latter case, there are other sources and methods which make a stronger case for the attainment of interchangeability.[257] Recently, in November 1987, Springfield Armory National Historic Site curator, Stuart Vogt, and Yale University professor, Robert Gordon, demonstrated to their satisfaction, in a test made at Springfield Armory, that a Hall rifle breech block made at Harpers Ferry in 1838 could interchange with one made by North in 1832. Many more such tests are required to evaluate published claims of interchangeability, and to understand the accomplishments of different armories in the formative

[253] This story appears in William P. Blake, History of the Town of Hamden, Connecticut, 1786-1886.

[254] Robert S. Woodbury, "The Legend of Eli Whitney and Interchangeable Parts," p. 247.

[255] S.N.D. North and Ralph North, Simeon North, First Official Pistol Maker of the United States, p. 106.

[256] Carrington, Sage, and Bell to Bomford, January 6, 1827, reproduced in U.S., Ordnance Department, A Collection of Annual Reports..., Vol. I, pp. 153-57. The report states that the receivers of a test lot of rifles were disassembled, but does not explicitly state that they were successfully reassembled from the mixed parts.

[257] Thales L. Ames, "Captain John Hall: His contribution to the art of arms," pp. 346-9.

period of interchangeable American small-arms manufacture.

Ordnance Department Attainment of Small Arms Interchangeability: Chronology, and Problems of Interpretation

For artillery officers like Decius Wadsworth and George Bomford, the successful late 18th century French development of interchangeable gun carriages was probably more influential than Blanc's or North's work. Inspired by visions of new, field-repairable American artillery, Wadsworth believed standard patterns could be developed for all ordnance classes.[258] When these artillerists tried to apply such standards to small arms, however, they soon found that differences of opinion, interpretation, and method prevailed. As comments of Prescott and others indicate, not everyone in the Ordnance Department believed that complete interchangeability in muskets was desirable, necessary, or feasible.[259] Although the doubters' views did not prevail, the men closest to small arms making problems probably had different priorities and objectives than the department staff in Washington. It appears that ordnance officers directly responsible for small arms applied the artillerists' ideal towards a more immediate and practical concern than making almost self-repairing weapons. These men wanted to assure the quality of arms produced or procured by the Army. To the small arms makers, quality was not always synonymous with perfect uniformity. The most pressing problems in 1815 were the related ones of quality control of finished arms, high failure rate of barrels in proof, and continued reliance upon private contractors for small arms supplied to state militia. As we saw in chapter 2, contracting for small arms remained a major component of military procurement until after 1840.

Meeting with his most trusted small arms makers soon after the 1815 reorganization, Wadsworth initiated a three-part, very general, response to these problems as an approach to uniformity. First, the department and its armories would design small arms models suitable for standardized reproduction at all public and private plants. Second, the national armories would establish manufacturing and inspection procedures for such reproduction. Finally, private contractors would meet

[258] Wadsworth to the Secretary of War, August 8, 1812, RG 156/5.

[259] James Dalliba, "Armory at Springfield," American State Papers, Military Affairs, vol. III, p. 553; Lee to Waters, June 8, 1819, quoted in Deyrup, p. 88.

similar standards to assure that all arms in service were of comparable quality.[260] At this time, the basic proposed method was creation of better and more uniform pattern pieces, representing an advance in orderly procurement but no very dramatic new manufacturing or quality control systems. The extent of uniformity in this plan remains unclear. During the next seven or eight years the chiefs of ordnance evidently scaled back their expectations in response to Armory difficulties in making interchangeable pattern muskets, and probably to Armory definitions of what was practical and necessary.

Under Roswell Lee's leadership, Springfield Armory's advances in interchangeable manufacture c1815-22 focused less on complete dimensional uniformity than on limiting the most common and expensive sources of musket or musket component failure, and on developing inspection gages to assure conformance of contract and armory products. As a planned set of actions, most of the former improvements involved barrel welding, boring, and finishing, as we discuss in chapter 7. The most important Armory industrial innovation of this period, Thomas Blanchard's first line of water powered gunstocking equipment, emerged more fortuitously in the climate of active regional technological transfer encouraged by Lee. Except to assure that all lock assemblies would be interchangeable in stocks, there was no attempt to develop completely uniform lock parts. This approach suggests that uniformity for field repairs was at least initially a low Armory priority.

A report from the Pittsburgh Arsenal of an 1828 inspection of 100 Springfield muskets provides an unusually good indication of the interchangeability achieved at Springfield by 1820.[261] At Colonel Bomford's instruction, the arsenal commandant, Capt. R.L. Baker, and Master Armorer Benjamin Moor made extremely detailed examinations of 82 muskets made in 1819 and 18 muskets made in 1820. Moor later became master armorer at Harpers Ferry, and played important roles in development of some Army musket and rifle models.[262] This report is one of very few we have seen which documents interchangeability of Springfield arms from any period, and for this reason and others noted below is of some interest. Some of the principal findings from this inspection follow.

[260] Smith, "Army Ordnance," pp. 51-7.

[261] R.L. Baker, "Report of an Inspection of 100 Springfield Muskets 1828," SANHS.

[262] see chapter 8 below, and Smith, Harpers Ferry, p. 278.

> Action of the locks. All of the locks but one functioned but the trigger pulls among them was very variable, ranging from 7 to 27 pounds. This problem was attributed to badly formed notches in the tumbler, and to variation in the angle of the sear.
>
> Measurement of lock parts. About 280 dimensions were measured on each lock.[263] The report recorded the greatest and least values of each dimension. On the tumbler, for example, 21 dimensions were measured; the average of the extreme variations reported is 0.03 inch. There is evidence that the measurements made in 1828 are reliable. Gordon measured five of these dimensions, with modern instruments, on tumblers made in 1830 and 1839 (the same model musket as those inspected in 1828): all measurements fell within the ranges quoted in the 1828 report.[264]
>
> Test of lockplate shape. A hardwood mold of one lockplate was made, and all other lockplates tried in it. Only 10 fitted; the others varied enough in shape to extend beyond the edges of the mold at one place or another.
>
> Interchangeability tests. Five locks were disassembled and all possible exchanges of the component parts made. Of the 20 possible interchanges,[265] the fractions that actually interchanged were: pans, 0/20; hammers, 3/20; tumblers, 10/20; bridles, 6/20; sears, 14/20; mainsprings, 14/20; and sear springs, 4/20. Moor and Baker made similar tests of the fit of metal parts to stocks and of the bayonet to the barrel, with generally similar results.

The 1828 report shows that the Springfield product in 1820 was substantially improved from what it was prior to 1815.[266] It is also clear that in 1820 the Springfield product fell well short of practical interchangeability, although the work of Baker and Moor was far more detailed than a normal inspection of finished arms, and so may not represent the contemporary standard of acceptable interchangeability. Roswell Lee was probably being optimistic, or was taking advantage of the ambiguities inherent in the term "uniformity," when he wrote to Colonel Bomford just a year later that "our muskets are now substantially uniform."[267] With the issuance in 1823 of new pattern

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[263] This means that 28,000 measurements were taken; if done at a rate of 4 per minute, the measurements represent 117 hours of labor.

[264] Robert Gordon, "Who turned the mechanical ideal into mechanical reality." The ability of Benjamin Moor to record measurements to thousandths of an inch in this report is both impressive and mystifying, as we have no idea of what instruments he used in 1828 to achieve such exactitude.

[265] E.g., take part A from Lock 1 and try it in locks 2, 3, 4, and 5; then take part A from lock 2 and try in locks 1, 3, 4, and 5, etc.; 4 x 5 = 20.

[266] For earlier descriptions of specific faults of Springfield muskets, see Hodgdon to Ames, September 1, 1796, Letter Book A, copied in D.S. Whittlesey, "Extracts, and Lechler to Monroe, October 21, 1814, RG 156/21.

[267] quoted in Smith, "Army Ordnance," p. 60.

muskets, gages for inspectors, and inspection regulations, the Ordnance Department completed the framework for most of the objectives outlined in 1815 under Col. Decius Wadsworth. Success in enforcing even limited uniformity among Armory or contract arms took much more time, however. It took another decade for improved manufacturing and inspection methods to make contract and Armory products really comparable in quality, and another two decades to create more or less interchangeable small arms.[268] Bomford's leadership was critical in achieving this latter goal, since he favored and encouraged development of mechanical methods, and lobbied strongly for funding. Given his problems instilling enthusiasm for uniformity at Harpers Ferry, and his necessary reliance on independent improvements centered on Springfield Armory, the prolonged gestation of interchangeable small arms making is not surprising.[269]

There were continued improvements in dimensional uniformity made at the Armory after 1815, and much of our subsequent discussion of manufacturing technology developed or used there concerns how these improvements were achieved. Growing mechanical skills among the artificers, improved methods of gaging and inspection, and better tools all contributed. The most rapid progress was made between 1815 and 1849. Successive superintendents, master armorers, and master mechanics pursued this objective following Roswell Lee's arrival. Interchangeability had nearly been achieved in 1848, by which time locks were apparently assembled from bins of parts with a little filing by the assembler to make the mechanism work smoothly.[270] By 1849 lock parts were being made sufficiently alike that they could be hardened before assembly.[271] This latter achievement can be considered the attainment of practical interchangeability at Springfield Armory, by one of the definitions mentioned above.

It is still unclear from available evidence how much individual fitting of finished parts may have been required after 1849, since this subject is rarely mentioned in Armory documents. There was

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[268] Bomford to Cass, December 28, 1833, reproduced in A Collection of Annual Reports ..., vol. I, pp. 264-69; Smith, "Army Ordnance," pp. 60-1.

[269] Smith, Harpers Ferry, pp. 83-4, 220, and "Army Ordnance," pp. 51, 62.

[270] Anonymous, Marco Paul's Adventures in Pursuit of Knowledge. Springfield Armory, p. 100.

[271] U.S., Congress, House, Superintendents of National Armories..., p. 91.

still some hand filing during production until perhaps 1931;[272] burr removal and surface smoothing by hand are still common practice in American manufacture. After 1849, the rate of improvement in attaining interchangeability slowed from its more rapid pace in the previous 34 years. When production of the bolt action magazine rifle began after 1892, the increased mechanical complexity of the mechanism, as well as new metallurgical requirements, seems to have exacerbated the difficulty of sustaining uniformity in production. By 1895 the Armory commandant reported that because of "more perfect" gages and an increase in the number of inspections of certain parts, the Krag was "practically interchangeable."[273] Scientific American called a later version of the Krag "the perfected model of '98, where all the parts are interchangeable."[274]

The next standard rifle adopted by the United States Army, the 1903 Springfield, was an interchangeable arm, but when a second production line was set up at Rock Island Arsenal in 1904, there were problems with the use of different manufacturing procedures and even different raw materials at the two government facilities. A leading authority on American rifles, Philip Sharpe, says that despite production problems a "reasonable degree of interchangeability of parts was maintained."[275]

The model 1914 Enfield, made for Britain in the United States by both Winchester and Remington, did not have fully interchangeable parts. Skilled men selected parts those that would fit into the particular rifle that they were assembling, from piles of parts. This selective assembly process was also used in the watch industry to reduce the need for hand fitting, but it was not considered acceptable by the Ordnance Department when ordering Enfields for American troops in World War I.[276]

The Model 1917 Enfield, made by the same private manufacturers under U.S. contract

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[272] ARSA 1931, pp. 4-7, 10.

[273] ARCO 1895, p. 7.

[274] July 28, 1898, p. 557.

[275] Philip Sharpe, <u>The Rifle in America</u>, p. 546.

[276] ibid, pp. 115-16; Landis, <u>Revolution in Time</u>.

specifications, had standardized parts, with interchangeability achieved even among weapons made by different factories. Assembly was apparently much easier than with the model 1914; one man could assemble more than five times as many weapons using the M1917 interchangeable parts. There were complaints about delays in getting the interchangeability system established during a period of critical shortages of military rifles, but more than two million M1917 Enfields were finally completed by the end of the war. The cost of each rifle was approximately $26, a significant drop from the $42 (later reduced to $30) paid by Britain for the 1914 Enfield. Some attribute this drop in cost to standardization of parts, but the decrease must also reflect the fact that most of the expenditures for equipment and set-up had already been made by the private manufacturers as part of the British contracts.[277]

Frederick Colvin, a manufacturing expert who was critical of the Ordnance Department in World War I, praised Henry Ford for making only subassemblies, not individual parts, interchangeable in the Liberty aircraft engine. "Strict interchangeability of all parts, especially those subject to wear, is seldom economical as many manufacturers know very well. Selective assembly saves time and money, and the replacements must allow for wear in any case."[278]

Interchangeability again became a problem when the M1 semi-automatic rifle was put into production in 1936, but the Armory achieved what was accepted as full interchangeability in this weapon. Tests conducted in the summer of 1943 showed that parts from different M1 rifles were enough alike to allow switching without hand fitting. The test was done according to the precepts established in the 19th century:

> “Ten M1 rifles of Armory manufacture selected at random from current production have been tested for interchangeability. All rifles were disassembled, components mixed, and ten rifles reassembled with no selection or hand fitting of parts. All reassembled guns functioned satisfactorily.”[279]

A combination of precision machining and careful component design made a truly interchangeable

[277] Sharpe, pp. 124-26. Sharpe claims the $42 initial Enfield cost; Williamson, Winchester, p. 226, claims the initial cost was $32. We have not resolved this difference.

[278] Frederick Colvin, Sixty Years with Men and Machines, p.198.

[279] Springfield Armory, "Monthly Report of Progress on Research and Development Projects," July 20, 1943, p. 12.

service rifle possible, but interchangeability continued to retain different meanings, even for Armory personnel. The M1 components of such high functional quality frequently failed to meet gage requirements, probably because tolerances on drawings were higher than required for satisfactory assembly.[280]

Interchangeability in Contract Arms

Reliance on contract arms was a major problem for the Ordnance Department until after 1840, particularly in procurement of weapons which were interchangeable among the various public and private armories. Springfield Armory was responsible for inspection of New England contract arms until 1830, and after that date remained a source of verifying gages used by the inspectors of contract arms. This latter responsibility began by 1821 and lasted through most of the Armory's history.[281] After 1840, the Ordnance Department regularly supplied manufacturing gages to contractors, with occasional contractor use of such gages earlier.[282]

The extent and pace of contractor progress in making interchangeable military small arms remains unclear, despite many documentary claims. After Simeon North's work for the Commissary-General of Purchases, the first such weapon recognized as interchangeable by the Ordnance Department (in 1827) was the Model 1819 rifle, designed by John Hall and made by him at Harpers Ferry Armory.[283] Simeon North made this same weapon interchangeable with Hall products by 1834, in what is said to be the first instance of multi-site manufacture of interchangeable military small arms.[284] Over a decade later the Model 1841 rifle, made by a number of contractors as well as Harpers Ferry Armory, was similarly credited with interchangeable manufacture among several locations. Springfield Armory did not make the M1841, which actually went into production c1846, and after 1848 Springfield did not produce any shoulder arms being made simultaneously by

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[280] Constance M. Green, "History of the Springfield Armory," Vol. II, Book III, pp. 743-45.

[281] e.g., Bomford to Lee, November 21, 1821, RG 156/1365; Green, "Springfield Armory," vol. II, pp. 10, 769.

[282] Smith's contention, in "Army Ordnance," pp. 60-61, that contractors received inspection gages in 1823 is probably incorrect. Most contractors received only pattern arms before 1840. Although contractor requests for gages apparently began in the late 1820s, Ordnance Department officers considered these requests unusual; see Deyrup, pp. 90-91; Green et al., The Ordnance Department, p. 19; and Bomford to Lee, January 23, 1828, RG 156/1365.

[283] Bomford to the Secretary of War, Jan. 31, 1827, quoted in Ames.

[284] S.N.D. and Ralph H. North, Simeon North; Smith, Harpers Ferry, p. 211-12.

contractors until the Civil War.[285] Based on documentary claims, it would appear that some private arms makers achieved full dimensional uniformity between two and twenty-two years prior to Springfield Armory.[286]

By c1855, the Ordnance Department had eliminated its reliance on contractors for shoulder arms.[287] When Civil War weapons procurement required new domestic rifle contracts, contract requirements for the 1861 and 1863 models in most cases included interchangeability with Springfield Armory weapons, with the Armory supplying pattern arms, gages, and inspectors.[288] After the Civil War, the Armory did not have to face the problem of interchangeability with another maker until the 20th century, first when production of the M1903 began at Rock Island, as mentioned above, and later when the M1 was manufactured by the Winchester Repeating Arms division of Olin Industries during World War II. The Winchester works had some difficulty attaining full interchangeability. In the 1943 test cited above, ten Winchester-made M1's were disassembled, their parts mixed, and ten rifles reassembled from the mixed parts. Some minor stoning and bending was needed to get two of the ten to function correctly.

By 1941 the Armory Gage Division had full technical responsibility for designing and procuring (usually through contractors) the final inspection gages for all small arms used by the Army with the exception of the M1917 30-caliber machine gun. The large number of contractors making 50-caliber machine guns during World War II required many sets of final inspection gages. Most of these gages were made by private shops and verified at the Armory. Final inspection gages for the M1903 rifle, produced during World War II by Remington, were not completed until 1943.[289]

B. Development and Application of Gaging

Early Objectives of Gaging Systems

[285] Smith, Harpers Ferry, Table 1, p. 181n; Flayderman, pp. 440-47.

[286] e.g., Battison, "Evolution of Interchangeability."

[287] see Flayderman, chapter IX.

[288] personal communication, Stuart Vogt, SANHS.

[289] Green, "Springfield Armory," vol. II, p. 219.

Until about 1820, small arms made at Springfield and other American armories were inspected with simple, qualitative procedures based on visual examination and inspectors' judgment. Inspection procedures in the first years of production at Springfield, apparently made after barrel boring, included proof firing, visual examination, a few simple measurements such as weighing the barrel, and trial of the action of the lock. These procedures, when coupled with the relatively undeveloped means of manufacture, were not sufficient to stem a disturbing tide of badly-made muskets. An examination of one of the earliest muskets revealed a long list of faults: the barrel was more than one pound heavier than the Charleville pattern and was unevenly bored and filed; the breech plug and the body of the cock were too short, the pan lid did not fit tightly; and the ramrod steel was "no good" and not well tempered.[290] Especially before 1807, many Springfield muskets had undersized breech plugs not well fitted to barrels, overly slender stocks prone to breakage, defective locks, weak bayonets, and badly welded barrels riddled with cinder holes.[291] Superintendent Benjamin Prescott probably began more regular inspections of musket parts during the manufacturing process, by the War of 1812. In addition to the procedures noted above, inspection under Prescott included examination of locks as they were filed, and of forged cocks.[292] More regular or intensive inspection did not, however, alter the basic means of quality control.

The Ordnance Department's determination to achieve uniformity in small arms from 1815 onwards was the driving force that led to the development of a more objective inspection system. As we noted at the start of this chapter, uniformity at this time meant, primarily, dimensional consistency among the parts of small arms, expressed as a requirement for interchangeability. In the early 19th century, the only way of testing for interchangeability was to demonstrate that a number of weapons could be assembled from parts chosen at random. This type of test made an effective and easily understood demonstration, but was not a practical means of quality control within an armory. The Ordnance Department's requirement for interchangeability led directly to a need for gaging methods that could be used by inspectors to test individual parts for conformity to a standard, and by

[290] Hodgdon to Ames, September 1, 1796, Letter Book A, copied in Whittlesey, "Extracts." Although there were decided problems with muskets made before 1815, it should also be noted that bureaucratic infighting involving the Armory during this era colored the representation of Armory products, with quality sometimes defined not only by the eye of the inspector but by the needs of his faction.

[291] Lechler to Monroe, Oct. 21, 1814, RG 156/21.

[292] Prescott to Wadsworth, July 15, 1813, RG 156/21.

artificers to test parts as they made them. Conformity to gage meant that the parts could be subsequently interchanged.

The national armories at Springfield, and to a lesser extent Harpers Ferry, introduced gaging to satisfy the Ordnance Department's requirement for uniformity in small arms. At Springfield, this process also provided Armory managers with a means of regulating the quality of the work of artificers producing parts for arms. For example, once gages were in use artificers could be paid only for the parts which they made to gage. For the artificers, this meant that their work could be evaluated against an objective standard instead of the subjective judgments of inspectors, which could be inconsistent and open to extraneous influences. The introduction of working to gage had important implications for the way that both artificers and supervisors carried on their work, but there is no evidence that gages were introduced for any reason other than the overriding quest for uniformity demanded by the Ordnance Department (see chapter 6).

Until about 1860, gaging was a new technology in most manufacturing industries, and it was developed most fully at Springfield, probably with cooperation and exchange of methods among many armories. As we discuss below, earlier gaging systems such as were used in 18th-century France were evidently for post-manufacturing inspection only; at Springfield, each artificer eventually had gages for whatever part he was making. Gaging became an important part of what became known as "armory practice," the "uniformity system" or "interchangeable manufacture," and helped establish the international influence of American manufacturing methods in the 19th century. Working to gage became the practical expression of the theoretical concept of interchangeability in making small arms. It was associated with, but not dependent upon, the introduction of machine tools.

Principles of Gaging Small Arms in the 19th Century

In the second decade of the 19th century, the only way that a standard American small arm could be specified was to adopt a "pattern arm," one sample that conformed to all requirements. The armories would then strive to duplicate this pattern as closely as possible. This method, in place by c1808, left open the question of how the pattern was to be duplicated, or how it could be compared with

production models.[293] Once the Army adopted the use of pattern arms, these questions quickly appeared as practical difficulties.

Today a requirement for uniformity would be expressed by specification of dimensions, with tolerances shown on drawings of the parts to be made. In 1815 neither the principles of dimensioning for mechanical work in a factory, nor the measuring instruments needed to compare parts with the specifications, were available. When a designer wanted to represent the parts of a machine mechanism, a scale drawing would be made, usually with no information about the precision required in the size and shape of a part, and usually limited to representation in one plane. Examples of such drawings, made by Acting Master Armorer, James Burton, at Harpers Ferry in the 1850s, have recently been found.[294] The technology needed for precise dimensional specification of manufactured parts was not developed until late in the 19th century, and the only practical means of establishing dimensional uniformity in 1815 was with mechanical gages.

The concept of a mechanical gage must be very old. One of the first recorded industrial applications was made by Christopher Polhem (1661-1751), who made gages for controlling the sizes of mass-produced items in Sweden.[295] The principle of a gaging system for small arms had been developed for the French Model 1777 musket. A set of gages for the inspection of this musket is preserved in the Museé d'Armeé in Paris, and must have been developed before 1814, when this model musket went out of production.[296] All surviving examples of 19th century gages used by Ordnance Department inspectors and the national armories are similar in design to the French gages, and the latter provide a useful typology of the gages developed for American small arms. However, the early gage design difficulties encountered at the American armories belie any immediate or direct transfer of the French gaging system, although the similarities between the two systems suggest a later, at least partial adoption of the French one. We discuss this latter point below.

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[293] E.g., Moller.

[294] These drawings are now at the Harpers Ferry National Historic Site. We are indebted to Herbert G. Fisher, Staff Archaeologist at the Virginia Division of Historic Landmarks, for apprising us of these drawings and providing us with copies.

[295] Anonymous, "Christopher Polhem, 1661-1751, The Swedish Daedalus," p. 27.

[296] One photograph of the 1777 musket appears in Louis André, "TPS spécialités de la métallurgie ardennais."

There were five basic types of gages in the French set used for the M1777 musket:

Patterns are models of individual parts made so as to facilitate comparison of an artificer's work with a standard.

A receiving gage is a mold cut to the outline of a part, which is tested by finding how well it fits into the gage.

A groove or hole gage is usually a slot or a hole cut in a metal plate intended to specify one dimension; the part is tested by inserting it into the groove or hole.

Limit or go/no-go gages specify upper and lower limits for a dimension. The only limit gages in the French 1777 set are the "go" and a "no-go" plugs for testing the bore diameter.

A thread gage consists of a short section of standard screw thread intended to show the thread form, pitch, and diameter.

Design and manufacture of a set of gages that would assure the interchangeability of all the parts in a musket was difficult task to complete in 1815 without measuring instruments or machine tools. This task, along with preparation and inter-comparison of duplicate gages, required a substantial investment most easily justified for a large production run of a standardized product. Gaging for large-scale production of uniform parts to close tolerances was first undertaken in the American small arms industry, and Springfield Armory's leadership in the first four decades of the 19th century was a major contribution to American manufacturing technology. Gaging also appeared in the clock industry at this time, but the tolerances required for clock parts were not as close as those required in small arms.[297]

Introduction of gages at Springfield Armory

The initial pace, nature, and direction of gaging at Springfield remain somewhat unclear in documentation we have seen, but appear to have involved more difficulty than is usually recognized. In response to instructions from the Ordnance Department in 1817, Roswell Lee and Master Armorer Adonijah Foot began to develop gages for inspection of finished muskets and for use of

[297] Donald R. Hoke, "Ingenious Yankees: The Rise of the American System of Manufactures in the Private Sector."

artificers during manufacture.[298] The best known early report on their progress is from Maj. James Dalliba's 1819 inspection of the Armory.[299] He stated that by this time, the Armory had adopted the principle of making each part to gage, and was perfecting the methods. Dalliba claimed the Master Armorer had a set of standard patterns and gages, that each foreman had gages for all the parts made in his department, and that each artificer had gages for whatever parts he was making. At face value, this claim means a number of gages equal to at least 98, plus twice the number of parts gaged, was required, and that these 150 or more gages had been fabricated at the Armory in just two years.[300] As we show below, the Armory had difficulty making 30 gages in a year in 1822, so it seems unlikely that 150 gages were in use in 1819. Supporting evidence is needed before Dalliba's statement can be accepted as a statement of work actually accomplished.

Dalliba's claims about gaging can be tested against the data in the 1828 inspection report on 100 Springfield muskets made in 1819 and 1820, discussed above.[301] The range of dimensional variation reported by Benjamin Moor makes it almost certain that the parts in the 1819 and 1820 muskets were not made to gage in the sense that we now understand the term, or as they were so made by 1842. An artificer can tell by sense of touch when a part differs from the dimension of a mechanical gage by about 0.001 inch, and can detect departures of a few thousandths of an inch visually.[302] Gaging that controls only the size of musket parts to within 0.03 inch is not a significant advance over control of dimensions by visual comparison of parts. Perhaps patterns for parts were being made at Springfield and distributed to the artificers from 1817 onwards, or perhaps Dalliba was describing intentions rather than accomplishments, but we cannot read into Dalliba's report the conclusion that a system of gaging was in place at Springfield in 1819. The superintendents of the Springfield and Harpers Ferry armories were still writing of means needed "...to pursue the method

[298] Smith, Harpers Ferry, p. 109 and "Army Ordnance," p. 60.

[299] Dalliba, "Armory at Springfield."

[300] In 1819, 98 of the 244 workmen were bringing parts to final dimensions (35 stockers, 12 mounting filers, 42 lock filers,
and 9 drillers, millers, and turners). This estimate is conservative, and might also include 10 grinders and a large number of forgers. We estimate that 27 parts were gaged.

[301] Baker, "Report of an Inspection."

[302] personal communication, Arthur Goodhue, former toolmaker, Marlin Arms Co.

of testing the uniformity of the parts by verifying gauges" in 1821.[303]

Despite the French examples which inspired the chiefs of ordnance, the difficulties anticipated by Benjamin Prescott in 1815, and the largely independent American origins of armory practice, were reflected in the limited nature of lock uniformity and the uneven early pace of Armory gage development. The Ordnance Department attempted to apply national armory procedures for inspection of finished arms to contract work for the first time in 1818, but there was no attempt to introduce more than barrel caliber gaging into these procedures until 1821. Difficulties encountered in developing pattern arms with inspection gages before 1822 suggest the relative absence of either manufacturing gages, or the use of prior French examples.[304] The use of French musket design makes the apparent absence of French gage prototypes particularly striking. The prolonged, often frustrating emphasis on pattern arm and inspection gage development until 1823 tends to belie any suggestion of extensive manufacturing gaging before that time. When considered with the clear department policy of controlling the important contract arm component of Army small arms procurement, this same emphasis also suggests that inspection of finished muskets may have been the initial force behind development of national armory gaging systems.

By late 1821, the Ordnance Department had not yet been able to formulate an explicit requirement for a gaging system. At that time, Chief of Ordnance Bomford instructed Roswell Lee to make thirty muskets for possible use as pattern pieces. There was to be no deviation allowed in the barrel bore diameter, the outside muzzle diameter, the inside diameter of the bayonet socket, the form and dimensions of the lockplate, or the positions of the holes in the lockplate. The other parts were to be made "...as nearly conformable to each other as is practicable."[305] Bomford's injunction that "no deviation" be allowed suggests a limited appreciation of manufacturing realities. His instructions for a set of verification instruments to be made for the use of inspectors appear more realistic, calling for two plugs for the bore diameter, with one to pass through the barrel and the other not to enter. Other instruments were to be made on the same principle, and the difference between the verifying

[303] Stubblefield and Lee to Bomford, December 4, 1821, RG 156/21.

[304] Morton to Lee, March 4, 1818, RG 156/1365; Lee to Bomford, September 11, 1821, and Lee and Stubblefield to Bomford, December 4, 1821, RG 156/21.

[305] Bomford to Lee, September 21, 1821, RG 156/21.

instruments was to be "...as small as convenient for a skillful and attentive workman to conform to." Bomford's specifications probably grew from recommendations made by the Armory superintendents, especially Lee, to whose judgment Bomford entrusted selection and design of most inspection gages.[306]

One year after receiving these instructions, Lee had not completed the set of gages, showing both how difficult the task was and suggesting the lack of prototypes available to the Armory.[307] Each gage had to be hand filed and repeatedly compared to the pattern part until the gage maker's sense of touch or visual judgment showed that a satisfactory fit was attained. If too much metal were cut away between trials, the job would have to be started afresh. As we Show in chapter 6, there was a shortage of skilled mechanical artificers at the Armory before the 1830s, which must have slowed production of the needed gages. Nevertheless, by 1823 there were sufficient gages made so that the new contract arms inspection procedures included the use of a number of verifying instruments.[308] The description of the inspection procedures suggests that eleven gages were used, and that only the bore gage was of the go/no-go type; for all other gaged dimensions, the inspector's judgment determined the acceptable degree of fit of the part to the gage.

Development of Gaging and Interchangeability, c1825-1850

Documentary evidence suggests that Springfield Armory was not in the forefront of developing gaging or interchangeable manufacture in the 1820s and early 1830s. John Hall evidently designed and used a set of sixty-three gages to make his rifles interchangeable by 1827, and by 1834 Simeon North made rifles interchangeable with Hall's using gages of his own design.[309] Despite problems of relying on such evidence, discussed above, it is likely that Hall and North made more rapid progress towards use of manufacturing gages than other small arms makers before c1834-35. As his gages have evidently not survived, it is not possible to evaluate either his gaging system or its influence on Springfield Armory. By 1835, however, the Armory had a gaging system in place which became the

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[306] ibid.

[307] Lee to Bomford, August 31, 1822, RG 156/21.

[308] Ordnance Department, Regulations for the Inspection of Small Arms, 1823.

[309] North and North; Smith, Harpers Ferry, p. 211, and "Army Ordnance," p. 63.

basis for all such systems used there until after World War I.

Documentary and material evidence of 1830s gaging development at the Armory appears sparse, but available data suggest that there was a comprehensive gaging system in place before 1835 which included gages for manufacture as well as inspection. Armory inventories provide the total number of gages at the site for the following years:

Year	1834	1835	1838	1839	1842	1844
Number	382	482	566	666	754	754[310]

Armory work returns for January 1835 show that 109 artificers were doing metal forming or cutting operations, including forging. Of these men, 46 did only one task. There were also 17 artificers making stocks.[311] If we suppose that each artificer doing a single task required only one gage, and two sets of gages were used by the master armorer and his assistants, the 482 gages in the inventory could have sufficed for perhaps more than three gages for each artificer doing more than one task. This calculation is based on several other assumptions which we cannot now verify: that all inventoried gages were available for current use at the Armory;[312] that the 66 different verifying instruments used to inspect muskets by c1840, discussed below, approximated in number and type the gages needed for manufacture in 1835; that this number was no less than the corresponding number of different gages used in 1835; and that forging artificers required gages. Alternative estimates of the number and distribution of manufacturing gages at the Armory are possible, but all would indicate there were sufficient gages at hand to supply a gage for every artificer responsible for bringing any part to a specified size or shape before 1835.

The number of inventoried gages nearly doubled in the eight years between 1834 and 1842, with

[310] Sources: Inventory of Public Lands & Buildings, Ordnance and Ordnance Stores, Machinery, Tools and Materials on hand at the Springfield, Dec. 31, 1834; Inventory of Ordnance and Ordnance Stores on hand at Springfield Armory in charge of the Master Armorer, Dec. 31, 1835; Inventory of Tools at the Springfield Armory, Dec. 31, 1838; Inventory of Tools at the Springfield Armory, Sept. 30, 1839; Number of Tools on hand per inv. Sept. 30, 1842; Inventory of Tools in .. Service, June 30, 1844.

[311] RG 156/1371.

[312] Armory manufacture of gages for inspection of contract arms undoubtedly created periods when Armory inventories included gages not made for use in Springfield.

some of the increase probably attributable to development of the new M1840 and M1842 muskets. Inspection of the latter weapon required fifty-six gages.[313] The number of Armory artificers engaged in production work remained nearly constant between 1835 and 1845[314]. The number of gages at the Armory would therefore have continued to suffice for gaging every part of these muskets during manufacture. The M1842 musket was the first made at Springfield with complete interchangeability (after 1849).[315] Attainment of this goal, made possible by the development of a practical gaging system and a body of artificers with the skills to use them, had taken more than thirty years.

The technology of gaging diffused rapidly throughout all of the small arms industry that manufactured for the U. S. government by the mid 1840s. The M1841 rifle was made at the Harpers Ferry Armory, and under contract by Robbins, Kendall & Lawrence/Robbins & Lawrence, E. Remington, Eli Whitney, Jr., the Palmetto Armory, and George W. Tryon.[316] Gages used by the makers and government inspectors of the M1841 helped maintain dimensional control on the parts for these rifles, which are believed to have been fully interchangeable.[317] If true, this claim suggests that this level of uniformity may have been attained before the Springfield Armory achieved it with the M1842 musket, although the relative extent of interchangeability among M1841 rifles remains untested.

Gage design before 1850

The earliest data we have seen on Armory gage design after 1823 is a list and description of instruments used for musket inspection c1840, which includes the following types of gages:

27 groove gages
17 receiving gages
7 patterns
3 gage mandrils

[313] Ordnance Department, Ordnance Manual, 1850.

[314] e.g., Felicia Deyrup, Arms Makers of the Connecticut Valley, p. 245.

[315] U.S. House of Representatives, Superintendents of National Armories, p. 91.

[316] Norm Flayderman, Flayderman's Guide to Antique American Firearms, p. 446.

[317] e.g., Battison, "Evolution of Interchangeability."

3 tapped gages

2 bore plug gages

1 barrel length gage

1 stock gage

1 breech screw tap and size die

1 screw wrench gage

1 screw plate for gaging screws

1 barrel vent gage

1 apparatus for testing the stiffness of the main spring.[318]

Most of these gages are of the same types used to inspect the French M1777 musket, although several of the Springfield gages combine two or more of these types in one unit. The gage mandrels are a type of receiving gage for testing barrel bands. The tapped gages were used to test screw threads. The function of the screw wrench gage eludes us at present. Every musket part, even the most insignificant, could be gaged with this set, providing for a much more comprehensive test than did the eleven gages used for contract inspections in 1823. The similarities in type, and, as noted below, design of gages from this period to the French set suggests that the gaging system used at the Armory by the mid-1830s developed from the French inspection methods. Only the bore plugs, which specified the maximum and minimum bore diameters, and perhaps the scale for measuring main spring stiffness, are limit gages. All other gages listed above required an inspector's judgment to assess conformance of a part to a gage.

The rapid progress in gaging made at the Armory after c1823, and the similarity of Armory gaging to the system used for the M1777 French musket, suggest several possible lines of development. In addition to independent invention by Armory employees, or their adaptation of gaging designed by Hall or North, it is also possible that an intensive Ordnance Department examination of French muskets and manufacture methods stimulated gage development at the Armory after 1830. The department sent Lt. Daniel Tyler to France late in 1829 to procure small arms samples and

[318] Springfield Armory, "List of one set of Verifying Instruments for the Model Musket of 1835," SANHS. Although designed in 1835, this musket went into production in 1840 and is usually designated by the latter year, so that the gages listed may not pre-date the era of actual production; see Flayderman, p. 441.

information on arms production.[319] As we discuss in chapter 8, the results of this trip formed part of the basis for a department examination of French and American muskets, made between 1830 and 1835 to help develop a new model. Tyler was a major participant in this examination. Although any direct influence of his trip on Armory gaging designs remains undocumented, the apparent contrast between the hesitant advances of 1821-22 and the more extensive system in place by 1835 makes the timing of the trip very suggestive. Further research may reveal that French influence on American military small arms was very selective, and consisted of borrowings, made at different times, of separate elements from what were originally unified systems of design and production.

A number of small arms gages from the 1840s survive in collections, and Dixie illustrated some gages actually used at Springfield in those years, so we can be quite confident about the design of the gaging system developed in the 1830s.[320] The gages from Springfield illustrated by Dixie are quite similar to the corresponding items in the complete set of inspection gages for the M1841 rifle at the National Museum of American History. This set may be taken as representative of inspector's gages at that time, so that comparison with gages illustrated by Dixie suggests that artificer's gages were probably similar to gages used by inspectors. Since there is apparently very little documentation, for any period of Armory history, on differences between gages used in manufacture and those used for different stages of inspection, the similarity noted here is important for any discussion of interchangeable manufacture at Springfield.

The gage set for the M1841 includes patterns, receiving gages, thread gages, and groove, hole and plug gages similar in design to those in the French 1777 gage set. It also contains several location gages, which show the relative positions of different parts of the weapon, such as the location of the cone relative to the breech. Author Robert Gordon examined these gages, and found that they were all made by hand filing. They do not have the elegant finish found on the French gages and are strictly utilitarian in style; scribed lines used for layout are still visible on some of them. Although Dalliba described the gages supposedly used at Springfield in 1819 as made of hardened steel, the gages in the M1841 set appear not to have been hardened (except for the barrel plug gages) and so

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[319] Bomford to Tyler, Nov. 30, 1829, and Bomford to the Secretary of War, Jan. 12, 1830, reproduced in A Collection of Annual Reports..., Vol. I., pp. 185, 202-203.

[320] E.A. Dixie, "Some old gages and filing jigs."

would be subject to loss of accuracy through wear. The only limit gage in the set is the go/no-go plugs for the bore; these differ in diameter by 0.009 inch.

Later 19th century gage development

As late as 1861, there were still some unresolved technical difficulties with the Armory gaging system developed in the 1830s at Springfield, including problems arising from an inaccurate lead screw in the lathe used to make standard breech plug threads.[321] However, this system generally answered Ordnance Department requirements because Armory managers introduced few changes in it during the rest of the 19th century. Master Armorer Erskine Allin's list and description of gages used to make the .45 caliber breechloader after the Civil War closely matches the types of gages listed above for c1840. Although there are no drawings with Allin's description, and no available examples surviving in collections, the descriptions leave little doubt that these gages were identical in principle to those used thirty years earlier.[322]

Later 19th century changes in gage design and gaging practice were gradual and evolutionary. Gages used for the M1873 and M1884 breechloading rifles were the basis of the gaging system developed for the Krag rifle, and the system used for the M1903 rifle grew from that used for the Krag.[323] Designs used for some M1841 rifle gages reappear in gages used in 1916 for the M1903 rifle.[324] Economy measures at the government armory often led to modification of old gages for new rifle designs. In general, it appears that the conservative preferences of Armory and Ordnance Department managers towards continuity of manufacturing processes is reflected in gaging systems developed between c1835 and 1905.

Although gage design changed little for many years, the number of gages used for each model of rifle made after the M1840 musket increased. The number had more than doubled by about 1873,

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[321] E.G. Parkhurst, "Manufacture by the system of interchangeable parts."

[322] Erskine Allin, "List of Verifying Gauges for Springfield Rifle cal. .45."

[323] Earl McFarland, "Gaging the Springfield Rifle.”

[324] E.g., compare Fred H. Colvin and Ethan A. Viall, United States Rifles and Machine Guns, figures 27, 46, and 159, with gages in the 1841 set.

when the model of that year required 154, and ballooned to 1,924 by 1916.[325] The Armory's gages were by far the most valuable items in the tool inventory during most of this period, in terms of both cost and product control. By 1872, for example, the Armory had 6725 gages valued at $42,031; the only other tools at that time valued at more than $10,000 were drop-hammer dies ($24,093), and milling cutters ($15,921).[326]

Gaging and measurement in the 19th century

Available inventories of the tools at Springfield Armory in the 19th century show remarkably few measuring instruments. Table 3.1 shows the tools that would have been needed for layout work and measurement, as listed in inventories for representative years. It is remarkable that in 1834 the Armory had but a single straight edge and five scribers, the basic tools needed to lay out gages. The increase in these two items between 1834 and 1838 may well represent the acquisition of the tools needed for the large number of gages then being made. It appears that the Armory in the 1830s had no way of laying out work to dimensions expressed in linear or angular measure, since there are no graduated instruments in the inventory. The gage making process must have been entirely a matter of fitting each gage to a part in a model musket. The number of all of these tools is far less than the number of artificers who were bringing parts to final form, and it is clear that these artificers did not use measuring equipment.

Table 3.1.
MEASURING AND LAYOUT TOOLS AT SPRINGFIELD ARMORY, 1834-1872[327]

	Number, in Years Inventoried			
Tools	1834	1838	1842	1872
Calipers	9	21	34	29

[325] James G. Benton, The Fabrication of Small Arms for the United States Service, pp. 128-36; Colvin and Viall, p.

[326] U.S., Congress, Senate, ...The Cost of Manufactures at the National Armory..., pp. 13-21.

[327] Sources: Inventory of Public Lands & Buildings, Ordnance and Ordnance Stores, Machinery, Tools and Materials on hand at the Springfield, Dec. 31, 1834; Inventory of Tools at the Springfield Armory, Dec. 31, 1838; Number of Tools on hand per inv. Sept. 30, 1842; ...The Cost of Manufactures at the National Armory....

Dividers	7	15	31	--
Graduated Steel Scales	-	--	--	12
Scribers	5	71	83	89
Squares	14	26	36	69
Straight Edges	1	38	50	71

It is reported that in 1842 the Springfield Armory acquired a set of weight and measures, standardized by Ferdinand Hassler of the U.S. Coast Survey, to aid in the manufacture of model arms.[328] We have not found any evidence of this set in the inventories, nor indications of their use at the Armory. Ambrose Webster describes a device used at the Armory in 1848 for graduating steel scales by transfer of divisions constructed on paper with dividers. These must have been among the first graduated rules used at the Armory.[329] A vernier caliper measuring to 0.001 inch is illustrated by W. Wade, who used it for measuring mechanical test specimens in the early 1850s.[330] This would have been a research instrument rather than something available on the shop floor, but it shows that the Ordnance Department had precision measuring equipment available for research purposes at least. The earliest evidence we have seen of Armory use of vernier calipers dates to 1877-78, when some calipers were tested for apparent research use.[331]

The lack of measuring instruments for use by artificers meant that nothing was to be gained by specifying dimensions on drawings: an artificer simply could not use dimensions under these conditions. It appears that 19th century drawings of both machinery and small arms parts, such as those prepared by James Burton at Harpers Ferry, were made either full size, or to scale without any dimensions shown.

[328] Deyrup, p. 145.

[329] Ambrose Webster, "Early American Steel rules."

[330] W. Wade, "Descriptions of the testing machines, hydrometer, and other instruments, employed in testing materials."

[331] ARSA 1878, in RG 156/21.

There were important developments in measuring technology for use in manufacturing, beginning around 1851 when Brown and Sharpe made their first vernier caliper for use of mechanical artificers. Shortly thereafter they began to sell graduated steel scales. The most important 19th century development was the introduction of the micrometer caliper in 1867[332] which made it possible for an artificer to work to specified dimensions to within 0.001 inch, i.e., to as close as could be done with a gage. The micrometer also eliminated the need for the manufacture of large number of gages when a new product was introduced, since it was only necessary to specify the correct micrometer setting for each dimension to be checked. It appears that the Armory did not yet own a micrometer caliper in 1872;[333] a large, undated micrometer caliper now on display in the Armory museum appears to be from about the turn of the century. Dimensional measurement apparently still had little place on the work floors of the Armory in 1872 since there were only 15 graduated steel scales listed in the inventory for that year. By the 1870s, companies such as Pratt & Whitney were developing gaging and measuring systems for industrial use on a large scale. It appears that Springfield did not participate in this development, but persisted in using a gaging system which met Armory needs from about 1840 to the end of World War I.

Mechanical artistry: Gaging the Model 1903 rifle

The gages used for the M1903 were conspicuous for their versatility. Fred Colvin, an editor of American Machinist who co-authored a detailed study of the manufacture of the Model 1903 rifle at Springfield Armory in 1916, paid a great deal of attention to the gaging procedures and to the design of various types of gages. He noted the frequent design of devices to gage more than one dimension or relationship. One gage for the guard "not only measures the width of this rear wall by the part C Fig. 1239, but also gages the width of the magazine and the location of the wall from the two screw holes as well as the height of the top of the guard from both tangs. It is a simple gage and contains suggestions that can be adopted in other classes of work." He also commented that two projections on it "help to locate the gage squarely on the work."[334]

The gages that Colvin described included all of the five basic types found in the French set for the

[332] Joseph W. Roe, English and American Tool Builders, p. 211.

[333] ...The Cost of Manufactures.. shows no such instrument in the Armory inventory.

[334] Colvin and Viall, p. 165.

Model 1777, plus a number of variations and later developments. There were many more limit, or tolerance, gages than in the Armory's gage sets from the mid-nineteenth century, possibly based on experiments made at Springfield in 1908 with gages designed to show tolerances.[335] There was more use of gages to set up machining operations correctly before the actual cutting began. Gages also played a greater role in assuring precise assembly and the proper relationship of one part to another. Headspace gages which looked like cartridges had been used for the Krag and were an accepted way of determining that critical measurement. They served as go no-go gages; the bolt should close on one steel cartridge form but not on another. Colvin describes another gaging system to help assure proper head space during the manufacture of the bolt. The gage was "practically a receiver," and the bolt was tested in it. He said that "[t]his method of using as a gage a piece into which the part fits, or a duplicate of it, is quite common here and has much to recommend it for general shop practice."[336]

Although Colvin criticized some Armory procedures and component designs that demanded unnecessary precision, he admired the gages in use and thought that other industries could pick up valuable ideas by studying them. Gages fell into his general and colorful category of "little kinks and devices," small technical achievements that made the Armory an effective producer of admirably (but not perfectly) uniform products. He was particularly impressed with fixtures that were used in gaging, remarking that many of these "inspecting fixtures" were "nice examples of the tool maker's art." They gave "an idea of the grade of skill required in a rifle shop tool room to produce satisfactory appliances.[337]

Among gun collectors and target shooters, a particular subset of the Model 1903 Springfield rifle is considered superior in accuracy to others: the so-called "star-gaged" Springfield, a rifle of legendary accuracy. Although not intended for combat weapons, it is significant that this gaging test has become a part of the folklore of American firearms, and indeed of American manufacturing. Proof of an extreme level of precision has bestowed a status out of proportion to any practical benefits accruing from that precision. The renown of the star-gaged rifles has spread far beyond the military

[335] ARCO 1908, p. 59.

[336] Colvin and Viall, p. 102.

[337] Colvin and Viall, pp. 13, 39, 97.

system that produced them and gave them their mark of distinction.

The star gage for the M1903 had fingers on it which formed a star pattern. The gage was used in the bore of the rifle to measure the diameter of lands and grooves. Armory inspectors used the gage along the length of the barrel and tested the variation in diameters that he found. Those barrels with almost no variation got a special designation (Philip Sharpe says .0001 inch was the allowable variation for a "star gaged" rating): they were stamped with a small star on the muzzle.[338]

The omission of a star stamp did not mean any flaw in the manufacture of a barrel. Rejection was the fate of barrels that did not pass the normal testing standards. Those that passed the gaging test without distinction simply went into service without the special star.[339] Sometimes rifles with star-gaged barrels were singled out for special tasks requiring accuracy. In 1909, the Armory did inspections of a large number of telescopic sights, which were attached to selected star-gaged rifles as part of an experimental project.[340] The special barrels (found by gaging to be special, but not specially-made - an important distinction) must also have played a part in the Armory's careful preparation of National Match firearms after World War I.

Despite the folklore surrounding the star gaged rifles, there appears to be no evidence to prove that the barrels actually produced appreciably superior results in firing tests. Many factors determine the accuracy of a rifle. Perhaps the star gaging was another example of obsessive concern with precision at Springfield Armory, a way of certifying and thus implicitly rewarding manufacturing tolerances that went beyond any reasonable demand.

Manufacturing tolerance problems and new gaging technology, c1919-1935

Despite its virtuosity, by 1919 the gaging technology used at Springfield had fallen behind that used by other manufacturing industries in the U. S. and by the makers of small arms in other countries. By this date the principle of manufacturing to established tolerances was well established. For example, maximum and minimum gages for specifying tolerances (acceptable limits) were in use at

[338] Sharpe, p. 115.

[339] ibid.

[340] ARCO 1909, pp. 49-50.

the Eskilstuna rifle factory in Sweden as early as the 1890s.[341] Springfield Armory use of tolerance or limit gages was not extensive, contributing to World War I difficulties in preparing private manufacturers for wartime rifle production. One Armory officer was only overstating the situation slightly in stating that, in 1917, the gages used for the M1903 had no tolerances; knowledge of the necessary degree of fit rested with the inspector's experience.[342]

Recognizing the tolerance problem for any emergency expansion of production using private companies, the Armory in 1917 contracted with the Greenfield Tap and Die Company (a leading maker of gages) for an entirely new gaging system. The contract called for Greenfield Tap and Die to determine all the tolerances of parts in the M1903 as manufactured at the Armory, and to place these on drawings of the parts. The company was also to design maximum-minimum gages for every tolerance shown on the drawings, and make two master gage sets for checking the working gages. The two sets of master gages were not to vary from one another by more than 0.0001 inch on any dimension.[343] Wartime production demands prevented completion of the contract, but the new gaging system was put in gradually after 1919. Three sets of master gages with templates were evidently submitted to the Armory in 1920.[344]

The Greenfield Tap and Die contract clearly indicated the extent to which Springfield Armory had fallen behind other industries in methods of gaging for the mass production of mechanisms by 1917. The fact that this project was contracted outside the Armory suggests that Springfield did not have the technical capability to design a modern gaging system that would be comparable to current industrial practice. The gaging system in place in 1917 satisfied the Ordnance Department's desire for uniformity, but in many instances was much too rigid, and could have been relaxed without adversely affecting the performance of the rifle.[345] We assume the same problem pertained for a significant proportion of the gaging of the M1842 musket (the first "interchangeable" arm made by

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[341] Torsten K.W. Althin, C.E. Johansson, the Master of Measurement, p. 42.

[342] McFarland, p. 368.

[343] Springfield Armory contracts, RG 154/1382, contract #120a, April 20 1917.

[344] ARSA 1919.

[345] Colvin and Viall; see also Colvin.

Springfield) and for the “trap door” and Krag rifles as well, although no detailed mechanical analysis to test this point has been done. It was undoubtedly difficult to be sure which dimensions had to be held to a close standard and which did not, but it is evident that the Armory never addressed this problem until forced to do so during the crisis of World War I.

Nothing in the Greenfield Tap and Die Company contract mentions final inspection gages, for use during rifle assembly after manufacture of components. The inspections of M1903 components at Springfield Armory were done with the same type of gages used in manufacturing--in other words, working gages. The master gages called for in the contract were for use at two different plants to check the working gages, including those used for inspection purposes. Thus the working gage forms, checked with very precise master gage sets at two plants, were to assure interchangeability of parts between rifles made at those plants. Final inspection gages for the Model 1903 rifle were not designed until 1943, and then the designs came from Springfield's own gage specialists, who by then had become very good at inspection gaging.[346]

The introduction of dimensional tolerances marked a new concept of uniformity at Springfield Armory. Arms might be interchangeable in the sense that they could be assembled from parts chosen promiscuously and yet not meet specified tolerances unless the tolerances were chosen to be just those needed to assure proper functioning. It was clearly difficult to determine such tolerances. The problem of deciding on reasonable tolerances for small arms parts, and of correctly entering such tolerances on drawings, continued to plague the Armory even after the new gaging for the M1903 was in place.

Development of gages for contract arms in the 1920s soon became a paradigm of the difficulties that could arise from having two standards of "interchangeability" in use. The idea of using just the working gage forms for inspections was apparently falling out of favor by 1924, especially for control of contract arms. The Armory was anxious to serve as the principal repository of dimensional control information for all small arms used by the Army, and secured a new assignment for its Gage Section in October 1924: to produce final inspection gages that would make certain that

[346] RG 156/1382, contract #120a, April 20, 1917; Green, "Springfield Armory," Vol. II, Book I, pp. 219-220. McFarland, p. 369, mentions "working and inspection gages" from Greenfield, but he may be alluding to gages used for, although not designed specifically for, inspection.

the components made by one manufacturer were fully interchangeable with those made by any other. This had been an Army objective since the manufacture of John Hall's rifles by Simeon North in the 1820s and 1830s, seldom working as well in practice as the Ordnance Department would have liked. The Army avoided this problem for decades by limiting contract arms, but World War I showed a clear need for mobilization planning with private firms.

The Gage Section's 1924 assignment covered the M1911 pistol, formerly made at the Armory but by this time manufactured in Hartford by Colt's Patent Firearms Manufacturing Company. The gage designs were based on drawings for the Colt pistol held at Springfield. After nearly seven year's work the gages were ready, and in 1932 were tried on parts manufactured by the Colt Company. The pistol parts did not fit the gages at all. Obviously Colt was not making pistols that matched the drawings. The Ordnance Department had proven that Colt was departing from the specifications, but what was it to do with this proof? The answer was to remake the gages to fit the pistol, which after all worked well and had required a heavy investment in tooling. The cost of rejecting so many pistol parts would have been greater than the cost of the gages. Once again, the Ordnance Department's dreams of perfection and complete uniformity had foundered on the shoals of reality, to use a Naval metaphor.[347]

The setback with Colt convinced the Ordnance Department that final inspection gages were definitely needed for all small arms. Although an embarrassment for the Armory, the episode probably worked to Springfield's ultimate advantage. The Gage Section (or division) gained not only added authority for small arms controls, but considerable experience for later M1 production. J. J. Callahan, head of the division in the 1930s led design efforts on final inspection gages for one weapon after another.[348] This effort contributed to the design of both working and final inspection gages for the M1 rifle, which was going into production at the end of the decade, and which was made at more than one facility. The idea of final inspection with special gages, which had originated as a way to check contracted products, was thus accepted, in principle, for Armory products as well.[349]

[347] Green, "Springfield Armory," Vol. II, p. 27.

[348] Ibid, p. 27.

[349] Ibid, p. 219.

M1 Rifle interchangeability and non-mechanical gages

The gages developed for the M1 fell into two basic classifications: working gages, most of which were snap gages with limits, and final inspection gages. The latter were far fewer in number but included more sophisticated forms. In the first nineteen months of the war there were approximately 3,800 working, or "manufacturing," gages and only 350 to 400 final inspection gages. However, as discussed below, inspectors were not actually using all of the final inspection gages for the M1 rifles made at the Armory.[350]

Working gages for use by machine operators were usually simpler than final inspection gages, although advanced technology for checking work began to have an impact during WWII. Most of the changes in gaging work in process on M1 rifle components involved greater use of tolerance or limit gages. Less judgment was involved in go or no go checks with the "snap gages" that had become standard forms in much of private industry. Snap gages, best described as fixed gages "arranged with inside measuring surfaces for calipering," were an old type. Some specially designed to check dimensional limits were in use for the Model 1903 Rifle before WWI, but these limit gages had their widest application at the Armory in the 1940s.[351]

The Armory manufactured a wide variety of weapons until 1942-43, and some 25,000 gages in all were "in daily use." As with some rifle components discussed in Chapter 7, World War II production demands were so enormous that Springfield had to turn to private manufacturers for its gages. In 1942, to give one wartime year as an example, the Armory purchased 19,489 gages from outside fabricators and made 1,634 gages in its own shops. Many of the gages were for outside contractors' use, but they were usually designed by Armory personnel and were checked for dimensional accuracy and quality by forty men and women in the gage inspection laboratory (who also did checks on incoming tools and fixtures).[352]

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[350] Green, "Springfield Armory," Vol. II, pp. 198, 475.

[351] We are indebted to Richard Harkins, who has examined the M1 gages at the Springfield Armory National Historical Park as part of his curatorial work. See also Otis Benedict, <u>Manual of Machine Shop Practice</u>, pp. 223225; Howard Munroe, ed., <u>Modern Shop Practice</u>, III, pp. 271-280; and Colvin and Viall, pp. 15-16.

[352] Green, "Springfield Armory," pp. Vol. II, pp. 198, 213-214, 219.

Although most of the modifications in gaging practice for wartime M1 production were more evolutionary than revolutionary, the Armory gaging section was now an important force for modernization. Gaging soon included indicator gages with dials. Comparators of various types came into use, with optical comparators becoming important devices for final inspection, and air gages replacing even some of the working gages on the shop floor.

Comparators represented the first Armory departure from the use of mechanical gages, starting in 1941 when several small optical comparators were put in the milling shop.[353] In the comparator, a magnified image of the part being examined is projected on a ground glass screen where it can be compared with a scale diagram of the part. Complex shapes and curves can be tested more easily by this technique than by conventional gages. The glass plates, produced in Buffalo from negatives of engineering drawings, were not subject to the physical contact with parts that wore out mechanical gages. The Armory and private contractors could get precise duplicates of plates from negatives on file. Changes in component form required less expensive gage modification when only an optical plate was involved. The use of comparators was soon seen as a great boon to manufacturing at the Armory, and by the last half of 1943 Armory gage specialists were teaching many contractors to use comparators in production.[354] By 1944, comparators were being used as the final inspection gages for many parts of contract arms, and for the inspection of milling cutters, hobs (gear cutters), and production gages.

The head of the gage division even predicted the total replacement of mechanical gaging by comparators that would be integral parts of machine tools. In 1944, one element of his dream came true when a grinding machine with a built in comparator went into use in the tool and gage shop. It was not a production machine, but it showed the potential of combined gaging and manufacturing equipment. In the meantime, large numbers of comparators had already gone into use in conjunction with the existing machine tools at the Armory, and the gage design section was busy making layouts for comparator plates. The section also had to design large numbers of fixtures to hold parts being

[353] Green, "Springfield Armory, vol. II, book III, p.356; William H. Davis, "U. S. Rifle Caliber .30, M1: History of Design, Development, Procurement and Production, 1936 to 1945," p. 91.

[354] Green, "Springfield Armory," vol. II, pp. 357-358; Lawrence E. Doyle, Metal Machining, pp. 52-55.

compared with the plate images.[355]

Despite these successes, the problem of deciding on proper tolerances continued as a major difficulty at the Armory through World War II and beyond. In 1941-3, when every effort was being made to increase production at the Armory, inspectors often found that satisfactory parts for the M1 rifle were being made with the use of gages that were off specified dimensions; in these cases a liberalization of specified tolerances was eventually recommended.[356] Clearly, the process of setting tolerances had to be one of continuing adjustment based on experience. However, these adjustments were only made slowly and through 1944 many rifles were shipped from the Armory that functioned properly and had satisfactory interchangeability but were made of many parts that were not to specified dimensions.[357] Without this use of "imperfect" parts, few rifles would have been completed. The success of the Armory in meeting production quotas was accomplished by reliance on the judgment of inspectors who knew which parts to pass, which was, of course, the situation that the Armory had wished to avoid when gages with tolerances were introduced after the World War I. As discussed below regarding inspection procedures, the Ordnance Department was not pleased with this reliance on the judgment skills of Armory artificers. Lt. Col. Gallagher, who became head of the Inspection Department in February, 1944, set out to see that every part was made to gage. This goal was eventually met but the immediate effect seems to have been that the Armory fell well behind its production quotas.[358] These experiences show that many of the problems of practical interchangeability that had developed in the early years of the 19th century were still causing trouble for the Ordnance Department and the Armory in 1945.

The demand for greater conformity to gages and drawings led to introduction of more gages for the M1 in 1944. There was less faith in the judgment of the wartime operators and inspectors. This increase in gaging can be seen as part of a much longer trend, however. Since the early 20th century, senior managers at the Armory had been losing confidence in the ability of employees to judge

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[355] Green, Springfield Armory," Vol. II, pp. 357-358, 594, 621.

[356] Ibid, p.218.

[357] Ibid, p. 473.

[358] Ibid, pp. 474, 479a.

precision. The use of more go/no-go gages (replacing many single dimension gages) in the 1920s was evidence of this trend. With a decline in the relative numbers of skilled men among the Armory employees in World War II, there was even less confidence. In 1944, the Armory tried to improve quality in various ways, but one of the most effective was by simply increasing the amount of gaging by workers, floor inspectors, and final inspectors. Where forty gages had been used on the M1 fixed base (an important component), the number rose to 52. The final inspection gages for the M1, which had numbered between 350 and 400 earlier in the war, became a set of 550.[359]

The Gage Inspection Laboratory began a program of regular verification of gages in 1944, replacing the practice of verification at the discretion of foremen and inspectors. The older method, which involved waiting until a high percentage of rejects indicated a problem with working gages used by operators, was no longer acceptable.[360]

These wide-ranging changes in gaging procedures which began in 1944 were needed most for the metal components produced in the Hill Shops, where the highest percentage of rejections was found. Comparative statistics at the end of the year showed that the Water Shops produced items "well within the quality level set" and far above those from the Hill Shops. Colonel Gallagher singled out the production of the M1 clip for special praise. This was a big change from the situation at the beginning of the war, when Garand was highly critical of the clips made at the Armory. The major change in clip manufacturing had come with a completely new production system in December, 1943, a system which included automatic electrical gaging.[361]

Engineers installed a conveyor system with a chain belt to take ammunition clips through multiple checking points for automatic inspection. Dimensions were measured at each point, and if any dimension fell outside the allowable limits, an electric contact sent a "plug" into action to knock the offending clip off the line into a hopper below. By simply looking at the accumulation in individual hoppers at each measurement point, inspectors (less than half the previous number required for final

[359] Ibid, pp. 350, 475, 620.

[360] Ibid, pp. 475.

[361] Gallagher Report of 18 January, 1945 quoted in ibid, pp. 614. Also pp. 483-484.

mechanical gaging) could tell what part of the manufacturing process was not performing correctly. This amazing process, three of which were in place by April 1944, could handle 3,000 clips per hour with one inspection machine, The Armory was even working on simultaneous checking of several measurements when the heavy demand for clips ended.[362]

Once the war ended, the Armory again became the repository for many thousands of gages. Contractors turned in their gages, and many from the Armory's own expanded operations became surplus. After World War I, the Armory had spent years carefully checking the accuracy of all the returned gages, but the costs and the unnecessary nature of that endeavor were still in memory. Now the Armory recognized that changes in weapons and gaging were occurring too rapidly to justify such effort on gages that might become obsolete in just a few years, if they were not already. Workers simply labeled and stored surplus gages after this war.[363]

In 1952, the Army was again under pressure to meet wartime demands for M1 rifles, this time in Korea. Upgrading of M1 production lines at the Armory and at private plants required close coordination with commercial manufacturers, and included extensive efforts to improve gaging. The Armory not only depended heavily on private suppliers for new gaging equipment, but also managed the procurement of these implements for its contractors. Its staff sent "approximately 5300 completed and semi completed components" to "various machine tool builders for work testing machines being built for outside contractors."[364] The inclusion of parts that were not finished shows the concern for accurate gaging of work at various stages of manufacture. The inclusion of completed parts may indicate several things: either there were inadequate drawings of finished parts; or the Armory wanted its contractor to check the ideal expectations of a drawing against the reality of finished parts; or gage manufacturers simply wanted to work with finished parts in setting up and testing the new gages.

Development of new gaging proceeded rapidly, but the Armory needed outside help. In the first six months of 1952, the "Gage Engineering and Design" branch had to deal with a mass of component

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[362] Ibid, pp. 484, 614.

[363] Ibid, p. 473.

[364] SANS, Jan.-June, 1952, p. 73.

revisions for various weapons as well as the problems of improving gage technology. The branch designed 135 new gages and revised 1,150 gage drawings because of the product modifications in that brief period. It also produced 85 new comparator plate layouts. A private contractor was chosen to "design Final Inspection Gages" for the M1, the BAR, and two machine guns. The contractor was also "to make Engineering Drawings of one hundred fifty-seven existing Comparator Plates."[365] Here, the Armory was once again manufacturing parts without a complete set of engineering drawings, a practice criticized during WWI by Fred Colvin and recognized in the Armory's 1917 contract with Greenfield Tap and Die, mentioned above. The drawings in this 1952 case apparently would be made to fit the existing gages (the plates of optical comparators). Greenfield had been asked to make drawings with tolerances based on the parts of the M1903 rifle, then to design gages reflecting the tolerances on the drawings. In the pistol-gaging fiasco of the 1920s, also mentioned previously, Armory engineers had designed gages to fit existing drawings which did not correspond to the pistols actually being made by Colt. The Armory, over time, had tried a variety of approaches to the production of drawings and gages.

The Korean War-era Armory Inspection Division put a high priority on the inspection of gages that were used for both "in-process" and "final" testing of components. Its staff checked the dimensions on 13,366 gages in 1952, devised a new internal control system for gages, and stepped up efforts to replace or repair faulty gages. Many gages, "while not to the latest design," were altered to perform efficiently. When large numbers of a particular component were rejected, the gaging methods and equipment were scrutinized with as much care as the machining processes. Inspectors looked for subtle problems with gage bedding locations and for obvious causes of rejection such as "variations between in-process and final gages."[366]

Gaging Problems after c1955

Armory development and pilot production of lightweight rifles, new .30" and .50" caliber machine guns, spotting rifles, and other new weapons produced heavy demands for new or modified gages. Newly purchased gages had to be dimensionally checked in the Gage Laboratory, and the volume was increasing. In 1956, the manufacturing shops were forced to go into production without gages

[365] SANS, Jan. - June, 1952, pp. 101-102.

[366] SANS, Jan. - June, 1952, pp. 99-104, July - Dec., 1952, p. 82.

for some components. "In many cases components were routed to the Gage Laboratory Branch for dimensional checks since gages were not available."[367]

Gaging technology kept improving during the 1950s and 1960s. To keep up with commercial practice, the Armory had to keep a sizeable staff working on gage design and inspection engineering, relying on outside assistance with many problems. Associated Engineers, Inc. modified a "German Barrel Straightening Machine," which allowed the Armory to both inspect and straighten barrels with the same machine. Springfield purchased a Panto-O-Jector fixture to inspect the M1 barrel chamber, thereby replacing 14 mechanical gages, and awarded a contract for designing "an optical gaging fixture to check the complete contour" of the operating rod helixes. Armory engineers also produced drawings for the contracted production of one set of "multidimensional gages" for the M1 receiver; these were special types of air gages.[368]

Air gages used for various measurements with the M1 and M14 speeded up production, reduced the problem of wear on gages, and eliminated the possibility of scratching machined surfaces that were being gaged. In 1956, the Gage Engineering and Design Branch began trials of its new, multi-dimensional air gages. These versatile devices allowed simultaneous checking of multiple surfaces on a particular component. Results were displayed on columns marked with established maximum and minimum values (analogous to the “go” or “no go” limits of mechanical gages). The Armory and private contractors applied this rapid and accurate gaging system during the production of the M14 receiver.[369] Well-documented problems with some of the contractors making the M14 made the gaging of its components particularly critical.

Gages of higher accuracy and more efficient form were steadily introduced at Springfield Armory, but the need for judgment by machinists and inspectors remained important until the closing of the facility. Although the Armory since World War I had been trying to reduce the need for judgment in gaging, it was never eliminated. There was still the demand for "visual examination" of surface finishes and workmanship. Men had to use gages properly, and they still had to make careful

[367] SAHS, July - Dec., 1956, pp. 50-51.

[368] SAHS, July Dec. 1953, p. 105, Jan. - June, 1955m, p. 64.

[369] SAHS, Jan. - June, 1956, p. 50; Walter J. Howe and Col. E. H. Harrison, "The M14 Rifle," p.19.

judgments when using mechanical form gages or the plates of optical comparators. Skill and experience were always a part of the effort to achieve uniformity through gaging and inspection.

C. Inspection Procedures

Gaging systems are no better than the people using them. It is apparent from our discussion of gaging that, through World War I, inspectors had to provide the manufacturing tolerances which barely emerged from the gages themselves. An Armory inspector "...literally carried the tolerances 'under his hat.'"[370] During the M1 era, the Armory wrestled with a problem it never successfully resolved: how to convert acceptable tolerances into inspection systems less reliant on individual judgments. Still obsessed with uniformity, senior Armory personnel were uneasy with the notion that the objective was subjective, for practical purposes. This unease was no doubt exacerbated by increasing Armory use of metallurgical testing on manufacturing stock and finished components beginning late in the 19th century. The ability to measure quality in the laboratory created a dimension of precision which was at once impossible to replicate in the shop, and frequently unnecessary for functional interchangeability. Dichotomies of this sort probably hindered 20th century Armory manufacturing progress.

Application of gaged inspection

We have little information on 19th century inspection procedures at the Armory. By 1835 the Armory had enough gages on hand for every artificer whose work involved bringing a part to a specified size or shape to have a gage for his own use. Except perhaps for barrels, discussed below, we infer that the Armory was then working under a plan of 100% inspection--every part was gaged at each stage of manufacture in which a dimension was established. The extraordinary records kept of "...almost every mechanical operation or act..." suggest this system was well in place by 1850, and probably emerged several decades earlier.[371]

The Master Armorer, his assistants, and the foremen in the individual shops were responsible for inspections of completed and assembled work, in an undocumented overlapping of authority, but

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[370] McFarland, p. 368.

[371] Jacob Abbott, "The Armory at Springfield," p. 161.

inspectors assigned to the foremen accepted or rejected the pieces which left the shop floors.[372] Inspectors appear in the Springfield work returns as early as 1830, but only represented a significant part of the labor expended in making a rifle or musket after 1860. By 1878 inspectors had risen to 9% of this total labor; in 1898 it was 7%.[373] Since most Armory work was paid for by the piece, with workers debited for rejections (see Chapter 6), one or a few men in each shop had considerable influence on the pay received by their fellow workers, and on any assessments of overall quality of a foreman's shop management. With the inspectors commingled with other workers in a shop, there were thus potential problems for inspection quality, including favoritism on the part of inspectors, hiding of failed parts by workers, and pressure from foremen on inspectors. We do not know how serious such problems actually became, but they clearly worried Ordnance Department managers at times. A board of inspection in 1841 noted that the Watershops--far from the superintendent's eye--was most prone to irregularities, and recommended replacing the four inspectors of these shops with a single, higher-paid inspector directly responsible to the superintendent, with the shop foremen to act as assistant inspectors.[374] These recommendations were probably not acted on.

It was apparently only after 1905, during the era of heightened Ordnance Department emphasis on efficient factory management, that Armory shop inspection systems were overhauled. Between 1906 and 1908, a chief inspector and his subordinates began operating as an independent Armory unit, removed from the foremen's control. These inspectors worked in separate rooms, and were forbidden shop floor contact with the workers. By 1911, workers turned in all work issued to them each day, finished or not, so as to eliminate illicit disposal of spoiled work.[375] Shop floor inspection evidently ended until a crisis of manufacturing confidence during World War II, discussed below.

The procedure of 100% inspection apparently persisted until the exigencies of wartime M1 production. In order to achieve maximum production, inspectors were allowed to exercise their judgment as to the number of parts of any given kind that were to be gaged. In any case, the

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[372] ARSA 1908, p. 11 confirms this inference.

[373] Springfield Armory work returns, RG 156/1371.

[374] Charles Davies, John Chase, and Daniel Tyler, "Report of the Board convened at Springfield, Mass., August 30, 1841 to examine the condition and management of Springfield Armory."

[375] ARCO 1907, p. 66; ARSA 1908, p. 11, ARSA 1911 p. 3

introduction of multiple station machines, in which parts were passed through a sequence of operations in one composite machine, precluded gaging after each operation. The exercise of inspector's judgment in sampling was suppressed by the introduction of standard sampling procedures by Lt. Colonel Gallagher late in 1944. An official determination of the number of pieces to be included in the inspected sample was made for each inspection operation. Only parts whose failure could result in direct injury to the user were subjected to 100% inspection.[376] This was the first use of statistical methods of quality control at the Armory. It was an important episode, outlined in some detail below, which exemplified many continuing limitations of traditional armory practice.

Despite continuing improvement in gaging technology, actual inspection practice in early 1944 did not rely heavily on gages. Only spare parts were subject to 100 percent inspection, and no reliable sampling program was yet in place to assure a sufficient check of parts being assembled. The most important test for M1 rifle components was apparently the test of assembly; if the parts assembled easily then inspectors could assume that they were within the allowable tolerances. There were also functioning tests and periodic tests of practical interchangeability. The M1 rifles needed so badly for the war worked well and by 1943 were meeting interchangeability requirements with ease, but did this really mean that they were being made to dimensional specifications at the Armory?[377]

The answer was no. If this seems surprising, we have only to look back at several examples from World War I. Fred Colvin remembered "the rifle that hung in the chief inspector's office at the Eddystone Plant at Remington.— every piece that had gone to make up the rifle had been rejected as unfit by a number of inspectors. The joker was that this very rifle when assembled turned out to be a fairly first-class weapon and made a good record on the test range." The chief inspector kept the rifle as a "shining example for inspectors who are inclined to be a bit too fussy about their work." Colvin also remembered that an officer at Springfield in that war had approved a number of bayonet blades which had already been rejected for straying more than .002 of an inch from the specified thickness. The officer, a combat veteran, "conceived the brilliant idea of using the bayonet scabbard

[376] Green, vol. II, p. 610.

[377] Green, "Springfield. Armory," vol. II, book III, pp. 320, 473; Springfield Armory Monthly Report of Progress on Research and Development Projects, May 20, 1942 - December 20, 1945: 1943, p. 12.

as the ‘go’ gauge...."[378]

The specifications for M1 rifle components at the beginning of the war were too restrictive. Not only was it impossible to meet all the dimensional requirements, but it was also unnecessary, as the practical tests of assembly, interchangeability, and functioning clearly showed. Gages were designed to conform to tolerances on the drawings of components. Even the gage-makers had trouble making gages to check these tolerances. The gage inspection lab was forced to use discretion before rejecting badly needed gages for slight variations in accuracy. Inspectors of manufactured components also had to accept minor variations in the products during the period of high M1 demand.[379]

Inspectors pushed the Manufacturing Department to make changes bringing products closer to drawing tolerances, but this objective was often impossible with existing machinery. Recognizing that some tolerances were unrealistic in terms of manufacturing capability and unnecessarily restrictive in terms of functioning, inspectors and production managers at the Armory demanded many changes on the drawings. When such changes were too difficult to arrange or too slow in coming, the only option for hard-pressed inspectors was to accept borderline cases in which failure to meet gage demands did not jeopardize the functioning of the M1. Lt. Colonel Gallagher observed that "the rifles functioned and were interchangeable, albeit not to every dimension. Thus to this degree the goals of quantity and model shop quality could not be simultaneously achieved." It was "indeed fortunate" that the M1 rifle was capable of good performance even when all its parts were not made to gage dimensions. He asked why, when some critical components made at the Hill Shops were averaging more than 50 percent "defective in respect to drawing tolerances," was it possible to get 98 percent acceptance in "final functioning"? This discrepancy is probably the principal reason that only about thirty of the 550 final inspection gages for the M1 had been in regular use up to 1944. Gallagher said in early 1945 that the Final Inspection Division had been forced "by the need of rifles, to accept pieces on a functioning basis rather than negotiate a change of manufacturing from Production Engineering or a tolerances change from Engineering." Final inspection at the

[378] Colvin, pp. 183, 192-193.

[379] Green, "Springfield Armory," vol. II, book III, pp. 218, 473-475.

Armory for most of the war was apparently not as rigorous as it was in civilian plants.[380]

Armory officials felt embarrassed by the fact that their inspectors were rejecting very few .50" caliber machine gun barrels, while statistics from Frigidaire Company showed a rejection rate of about 13%. The difference, in this case, was not quality, but inspection. In 1944, the Armory closely examined and began to reform its inspection system for the .50" caliber barrels and for the M1 rifle. Lt. Colonel Gallagher headed this overdue effort.[381]

The first step was to divide the final inspection responsibility between a new Manufacturing Inspection Division (not under the control of the Inspection Department) and a Final Inspection Division. The latter, as in the plants of government contractors, acted for the Ordnance Department, at least in principle. Gallagher implemented a "Standard Sampling Inspection" procedure for final inspections and set up special stations for these inspections, usually at the end of particular production lines. Here, the careful use of statistical sampling methods, as noted earlier in the uniformity section, provided a rational way to ensure sufficient quality without spending excessive time on 100 percent inspections.[382]

The rigorous program of floor inspection now under the Manufacturing Department gave close attention to changes in the accuracy of machines, fixtures, and cutting tools. Many inspectors were transferred to the new Manufacturing Inspection Division. The emphasis was on floor inspection at the machine rather than on bench inspection after a series of operations. Beginning with the M1 bolt, the use of floor and roving inspectors steadily spread to other parts of the rifle. Machine operators were also doing their own gaging of work in progress or completed. In 1945, graphs at individual machines charted quality at half hour intervals and could show problems developing at an early stage. Employees thus had warning of the need to sharpen tools or make other necessary adjustments before they exceeded any tolerances. Spoiled work, after all, hurt both the war effort

[380] Green, "Springfield Armory," vol. II, book III, pp. 382, 475, 492, 619, 759-761. See also 18 November, 1944 and 18 January, 1945 progress reports by Lt. Colonel Gallagher, quoted in Green, pp. 615-616.

[381] Ibid, pp. 492, 609-616, 759-760, 763-765.

[382] Gallagher, "Standard Sampling Inspection," 23 September, 1944, in ibid, appendix; see also ibid, pp. 759-760, 766.

and the individual's pay check.[383]

The war had hurt quality control in many ways by 1944. Machines, fixtures, and gages were wearing out under the heavy strains of almost round the clock production. Demands for more rifles and heavy machine gun barrels had forced inspectors to keep the number of rejections low and kept machine operators working at an accelerated pace. The draft, voluntary enlistments, and the expansion of manufacturing at the Armory meant the hiring of many new employees, who were usually unfamiliar with ordnance work. The decline in the number of skilled, experienced employees meant fewer operators and inspectors who could judge quality rapidly by simple visual checks.[384]

During the second phase of M1 production beginning with the Korean War, very similar problems reappeared. To avoid unnecessary rejections, an Armory Waiver Board took a hard look at some of the reasons for rejections, including tolerances that were apparently tighter than absolutely necessary. Here, the experience of the inspection reforms of 1944 and 1945 must have been helpful. In 1953, the board drew up a "Waiver list ... for the M1 rifle showing acceptable deviations from drawing limits." Ordnance inspectors checking the rifles made by contractors could use this list to permit "acceptance of material not exceeding the waiver limits" and to avoid the "processing of individual waivers."[385] Thus the concept of "acceptable deviations," which had probably existed in an informal way since gaging began at the Armory, and which was recognized as a problem by Lt. Colonel Gallagher's Inspection Department in 1944, was made formal and given official sanction. Nevertheless, contractors were still complaining about "unnecessarily small" tolerances for some M14 parts in 1961.[386]

Gallagher's success with relatively basic applications of mathematical sampling theories led eventually to development of the Component Inspection Procedures of 1951, which made use of all

[383] Ibid, pp. 500-502, 609-610, 759-760, 763-765; SAHS, July-December, 1945, p. 14.

[384] Green, "Springfield Armory," vol. II, book III, pp. 351, 459, 487, 489, 617-618, 620; Davis, "U. S. Rifle Caliber .30, Ml," pp. 69, 71, 92.

[385] SAHS, July - Dec. 1953, pp. 106-107.

[386] Walter Howe and Col. E. H. Harrison, "The M14 Rifle," p. 19.

the knowledge gained on gaging and testing at the Armory up to that time. A gage procurement program had been underway since 1950. It was designed to supply one set of final inspection gages to each facility making weapons for which the Armory had technical responsibility. The Armory requisitioned 13,146 gages with a value of $1,542,536. Its staff produced instruction manuals explaining in great detail the procedures for inspecting and ensuring the uniformity of weapons such as the M1.[387]

Other testing procedures for uniformity

Assuring a proper degree of uniformity involved acceptance testing of materials arriving at Springfield Armory for processing into components, and of metallurgical tests of finished parts. In some cases, the Armory required certifications by independent testing facilities that purchased materials met government specifications. The Armory, particularly in the 20th century, did most of its own evaluations of the results of manufacturing processes which affected the strength of metals, such as rolling, forging, and heat treating, or which altered chemical makeup as well as physical characteristics, such as case-hardening. Tests or judgments of content and properties were, of course, more sophisticated after the establishment of the chemical and metallurgical laboratory in 1917, but in at least rudimentary forms, they were as old as manufacturing at the Armory. The 1796 judgment that the steel of a ram rod was "no good" and its heat treatment deficient is one early example of a simple inspection process in the period before the Armory had even begun to use gages for checking dimensions.[388]

It is well established that barrel testing was based on the 100% inspection method from the earliest period of Armory musket manufacture. Barrels required a series of tests, which sometimes failed to intercept metallurgical flaws emerging from the numerous manufacturing steps. By 1810, barrels were inspected when bored, and again after grinding. Every barrel was proof fired twice as soon as enough work had been done on it to make firing possible, with 1/18-pound of powder and one ball.[389] Defective welds or poor iron were the leading causes of barrel failures, and it was clearly

[387] Gallagher, "Standard Sampling Inspection," 23 September, 1944, in Green, vol. II, appendix; also see Green p. 776, SAHS 1945 - 1951, p. 84, and U.S., Department of the Army, <u>SA-ITM-S200, Ordnance Inspector Training Manual, Rifle, U.S. Cal. 30, Ml</u>.

[388] Hodgdon to Ames, September 1, 1796, Letter Book A, copied in Whittlesey, "Extracts."

[389] Whiting to Eustis, January 13, 1810, Records of the Office of the Secretary of War.

desirable to detect these faults before much machining was done on the barrels. With this objective in view, Ordnance Officer P.V. Hagner experimented on proof testing musket barrels with hydrostatic pressure at the Watertown Arsenal in 1844. He used new barrels sent from Springfield by Major Ripley as well as old ones made by Waters in 1827. The test was made after the first boring so as not to waste valuable machining on bad barrels. The barrel to be tested was filled with water and a piston driven in to raise the pressure to 7,000 psi. Hagner succeeded in detecting bad welds that were not otherwise visible.[390] Springfield Armory purchased a machine for hydrostatic testing in 1845-46, presumably for this purpose, although we do not know if it was used.[391]

The concern shown by Armory officers and other employees for the quality of the iron and steel that went into its products can be demonstrated with thousands of documents. One can also see great attention paid to the quality of wood for gunstocks, of brass for various fittings, and of many other raw materials that were turned into the parts of Armory products. Direct, often uncalibrated mechanical tests in a manufacturing context proved effective in assessing quality, until sometime in the later 1890s. Colonel Buffington, the commanding officer in 1891, noted that castings supplied for the manufacture of firing pins did not have the necessary properties. No matter how precise the machining process that turned the castings into firing pins, the pins would not be hard enough to resist deformation in use. The ones sent to the Armory by the Aluminum Brass and Bronze Company were simply not the right kind. He wrote that they compared unfavorably with the "Lockport Metal 'Special Grade'." The alloy was a type of aluminum bronze, but Buffington did not provide chemical proof of the wrong alloy content or give quantified data on yield strength and ductility; he simply said that the ones sent to the Armory would forge cold and the "right kind" would not.[392] The "right kind" of casting was a prerequisite for uniformity of firing pins.

Selection of barrel steel for the new Krag rifle in the same decade was one of the most challenging aspects of early Armory magazine rifle production, and involved a great deal of scientific testing as well as practical judgments, often on the shop floor. The testing necessary to find a steel that could

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[390] P.V. Hagner, "Proof of musket barrels by hydrostatic pressure at Watertown Arsenal, 1844," pp. 95-7.

[391] ARSA 1846, in RG 156/1354.

[392] Buffington to the Aluminum Brass and Bronze Co., Mar 25, 1891, RG 156/ 1351.

be rolled and machined well, and would still hold up to the damaging action of the first smokeless powders, introduced the Armory to a new level of metallurgical sophistication, provided experience with some of the best testing procedures of the day (often done outside the Armory), promoted the use of quantifiable data on material properties, and impressed on Armory officers the need for regular, rational testing of critical materials and components.[393] Sampling procedures apparently became more formal in this period, although we have no evidence of real statistical sampling at the Armory until 1944. In 1899, Scientific American described a minimum pressure test for the chamber for every barrel and stressed that "ten or more barrels made from each new lot of steel delivered are subjected to a special test of 100,000 pounds to the square inch."[394]

The metallurgical testing capabilities within the Armory facilities improved in 1900, when new equipment was acquired. A Riehle testing machine with 50,000 pounds force capacity reduced the apparently heavy dependence on outside testing facilities, and allowed prompt determination of tensile strength and other physical properties of steels supplied to the Armory.[395] If steels were tested and found uniform in certain properties on arrival, then the Armory had every reason to assure that its manufacturing processes were consistent in their effects on these metals. For instance, no significant variation in the heat treatment given a particular component could be allowed. As we note in Chapter 5, however, tensile tests proved inadequate predictors of manufacturing quality control, because longitudinal barrel seams had little effect on tensile properties but could greatly affect barrel strength. The new apparatus in 1900 also included two pyrometers, the value of which was noted by the commanding officer: "There has always been an uncertainty as to the heats used in different operations of rolling, annealing, case-hardening, etc. By the purchase of two pyrometers, heats have been regulated with very satisfactory results as to uniformity of product."[396]

[393] Col. Mordecai to Chief of Ordnance, June 10, 1892, National Archives, PG 156/1354; Col. Mordecai to a list of steel producers, Sept. 14, 1892, RG 156/ 1351. Mordecai told the producers that "A metal is required that is not readily acted upon by the gases, from the new powders now coming into use. He gave them a general idea of physical properties necessary and asked for specimens 1 1/8" diameter by 7" for a testing machine, 2" diameter by 11" for a forged barrel trial.

[394] Scientific American, "Manufacture of Krag-Jorgensen Rifles at the Springfield Armory," p. 267.

[395] Since standard tensile specimens have a sectional area of 0.2 in .2, the Riehle machine could break test bars as strong as 250,000 psi, or more than required for Armory usage.

[396] ARSA in ARCO, 1900, Appendix 9.

The metallurgical and chemical laboratory installed in 1918 meant that the Armory could now do its own chemical analysis of metals, including purchased steels, and that it could do a wider variety of physical tests.[397] There was apparently no trained metallurgist on the Armory staff before A.E. Bellis arrived in 1917. His experience paid immediate dividends when he helped develop a new heat treating process for receivers and bolts. He was probably responsible as well for the use of a scleroscope to check the results.[398]

With the increased pressures generated in .30" caliber rifles, particularly after the adoption of the higher velocity 1903 cartridge, the strength of breech mechanisms became a serious issue. Case hardening of plain carbon steel receivers and bolts created lingering problems with brittleness until the improved "double heat treating" process (which still included a form of case-hardening) was introduced in 1918. Following that, machined receivers were tested for hardness using a scleroscope after the final step of the heat treating and hardening process. Surface hardness had to fall between specified upper and lower numerical limits on a standard scale.[399] This can be compared to the "go", "no-go" limits of dimensional tolerance gages which were also coming into greater use at the Armory at the same time.

Chapter 5 outlines the growth of Armory metallurgical expertise after World War I, in response to the need for control quality of procured steel. As this testing capability increased in scope and came to reflect the best practice of materials science, it made a significant contribution to the pursuit of uniformity in products. During World War II, the Armory added more men with expertise in metallurgy and chemistry. Employees also came into contact with some of the teams of top civilian scientists mobilized for the war effort under the National Defense Research Committee and the Office of Scientific Research and Development. The postwar period, as we will see in Chapter 8, put even more emphasis on the use of science to improve Armory products. It also gave the Armory a greater role in devising ways to assure uniform quality in products of commercial contractors, who would be taking over more and more of the manufacturing function of the arsenal system.

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[397] ARCO, 1918; ARSA, 1918.

[398] Julian S. Hatcher, "Metallurgical improvements in the Springfield Rifle," pp. 351-3.

[399] Sharpe, pp. 115-116.

Magnaflux testing of barrels was introduced early in WWII as a wet process in an oil bath. It was an old idea that had only become cost efficient when production was increased. Filings, when magnetized, would indicate small cracks in machined barrels. Unfortunately, the process was finding too many flaws after machining (it was necessary to have a machined surface to see the cracks with this wet process), and there was considerable question about whether rejections of the flawed barrels were justified. The flaws found were often not serious enough to cause any problems in proof firing tests. The situation was eased in the spring of 1943, when Armory engineers went to a dry magnaflux process. This dry process worked on rough barrel blanks before machining. Magnafluxing was also used, without any controversy, on receivers, bolts, and operating rods.[400]

By 1953, modern technology had suggested a new way to test for small flaws in rifle barrels. Sperry Products negotiated a contract with Springfield "for development of ultrasonic inspection equipment for the detection of flaws in Small Arms barrels and barrel blanks."[401]

D. Summary: Armory Uniformity and the Costs of Perfection

The scope of an ordnance inspector's responsibility, as outlined in the 1952 training manual produced at Springfield Armory for inspectors of the M1, expresses beautifully the whole concept of uniformity, and reflects the somewhat ironic lessons of more than a century and a half of experience:

> The purpose of Acceptance Inspection is to insure that procured supplies can satisfactorily perform their intended function. To accomplish this objective, it is essential that the requirements of the contract, drawings, and specifications are met. Inspection may thus extend to all matters relating to acceptability of product, including quality of materials, method of manufacture, manufacturer's inspection, and compliance with Government standards for workmanship, quality, performance, and interchangeability.[402]

Those three sentences summarize many of the contradictions of Springfield Armory practice in achieving uniformity, notably the long-standing tension between performances of "intended

[400] Davis, p. 81; Green, vol. II, pp. 232-234.

[401] SAHS, July - Dec. 1953, p. 106.

[402] SA-TIM-S200, p. 301.

function" and "requirements of...drawings and specifications." The years 1834 to 1842 were a period of remarkable technological change at Springfield. At that time, Armory managers developed a system of manufacturing based on the use of metal cutting tools to bring forged parts to approximate shape followed by hand filing to dimensions closely controlled by comparison with an extensive set of gages. Specification of dimensions by measurement was not used; quality standards rested with the interpretations of goodness of fit by artificers and inspectors. Once this system proved satisfactory for the production of uniform arms, it was not changed. Instead of evaluating gaging needs against product performance, the principle of uniformity was extended and refined in ways that may have been aesthetically satisfying but which had no economic basis. Commercial armories used gaging and interchangeability only to the extent that it was economic to do so.[403] More significant for later Armory history, Springfield retained its established procedures as commercial manufacturers developed new procedures for attaining functional interchangeability in the manufacture of railway equipment, bicycles, and automobiles in the late 19th century. Armory virtuosity in design and application of gaging systems was not matched by allowance for realistic manufacturing tolerances. After World War I, the Armory tended to follow commercial practices when new methods and standards were required for introduction of such tolerances. Although the quality and performance of Armory weapons was rarely exceeded, other industries eventually showed that they could make small arms more efficiently and at lower costs by not using traditional armory methods. In this way the Springfield Armory lost one of the principal reasons for its existence.

ABBREVIATIONS IN NOTES

ARCO	U.S., Ordnance Department, Annual Report of the Chief of Ordnance to the Secretary of War for the Fiscal Year Ended June 30, ----.
ARSA	Annual Report of Operations at the Springfield Armory. Titles vary, and reports appear in different archival sources, as noted.

[403] e.g., Robert A. Howard, "Interchangeable Parts Reexamined: The Private Sector of the American Arms Industry on the Eve of the Civil War."

RG 156/	Record Group 156, Records of the Office of the Chief of Ordnance, National Archives. Record entry number follows slash.
SAHS	Springfield Armory Historical Summary for the Period ----, on file at Springfield Armory National Historic Site. These are semi-annual or annual reports covering the years 1951-1965.
SANHS	Springfield Armory National Historic Site. This refers to material held by the National Park Service at Springfield.

Chapter 4

PLANT DEVELOPMENT AND THE CHALLENGE OF SPRINGFIELD ARMORY GEOGRAPHY

At the end of the 18th century, Springfield Armory's physical prospects as a large manufacturing center were singularly inauspicious. Few if any industrial enterprises of comparable size ever labored under such conditions, which from our present vantage appear almost surreal. The ability of Armory managers to create a large factory at this site by the mid 19th century, making complex metal products to unusually demanding manufacturing standards, was remarkable. Many of the managers prior to 1860 probably preferred a less remarkable image, and a more tractable location, but they had no place else to go: early investments in plant and equipment had made radical changes in location impractical. By the Civil War, the worst physiographic obstacles to development were overcome, but it took about 120 years and repeated rebuilding episodes after the Armory's founding to overcome most of the plant's formidable geographic limitations. The creation of more logical plant arrangements, with adequate power and fireproofing, dominated plant development strategies until the early 20th century. By World War I, site management objectives shifted to increasing the scale and efficiency of production, with more space, and with more efficient power generation and transmission systems to run faster equipment. This chapter summarizes the outlines of Armory plant development, focusing on buildings and power systems. Chapters 5, 7, and 8 describe equipment and operations in more detail.

A. Site Limitations

Springfield Armory originated as a Revolutionary War supply and storage depot, on the thirty-acre Springfield town Training Field. As noted in Chapter 1, the site was chosen in part because of its

security from naval attack. The training field was on a hilltop a mile east of the Connecticut River, with a steep north side and a long slope to the west, north of the principal road from Boston to Springfield. The site stood above and well away from any streams (Figure 4.1). Although the full extent of Revolutionary War operations is unknown, the focus was on storage, small arms repair, and construction of gun carriages and transport equipment. Depot personnel accomplished all their tasks in a small number of frame shops, with no water-powered equipment. There was evidently little additional plant improvement during the site's use as a federal arsenal for arms and powder storage from 1782-1794.[404]

The Training Field site was spacious enough for proposed arms manufacture in 1794, but lacked the waterpower which federal planners immediately recognized as an important defect. The committee sent by Congress to report on the suitability of the arsenal site for a national armory recommended that the armory be located instead on the Agawam River in West Springfield. When the citizens of West Springfield objected strenuously and made this choice impossible, the arsenal site with its disadvantages was adopted, on the assumption that the Armory would somehow function with less voluminous waterpower purchased nearby. The government began to purchase waterpower sites on the Mill River, a mile south of the arsenal site, in 1795. This first purchase -- the earliest made by the government for the armory, since the arsenal site remained a town property until 1801 -- established a basic division at the armory between shops on the river and shops on the hill (Figure 4.1).[405]

The Mill River was the closest source of significant water power to the arsenal, and the largest stream in Springfield. It flowed through a steep-sided valley cut in old lake-bottom sediments, but in the middle part of its course through the town it ran over bed-rock suitable for dam foundations. Although it served to power small mills and factories beginning in the 17th century, the river was

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[404] Derwent S. Whittlesey, "The History of Springfield Armory," Chapter 1, summarizes the pre-1794 history of the site. None of the manufacturing activities from 1777 to 1794 appear to have much bearing on Springfield Armory development as a small arms factory, beyond the fact that the Armory began with the buildings available on site in 1794. Edward C. Ezell, "Domestic Arms Manufacture during the Revolution: A Study of the Colonial Arms Factory and Arsenal at Springfield, Massachusetts," notes that wagon, saddle, harness, and boat manufacture was a major depot activity. The claim that cannon were cast at the depot, e.g., in Harry A. Wright, The Genesis of Springfield, p. 35, has never been confirmed, although SANHS curator William E. Meuse has encountered limited material evidence giving the claim some credence.

[405] Whittlesey, Chapter 4, Appendix 3.

not large enough to power fully a large industrial enterprise. The government attempted to alleviate the problem by a series of later purchases of waterpower sites, acquiring a second waterpower site by perhaps 1798, a third in 1809, and a fourth smaller site in 1817.[406] The first three sites, enlarged in some cases by later purchases, became known, respectively, as the Lower, Middle, and Upper Watershops. Use of the fourth site, above the Lower Watershops, is less well-documented aside from its temporary use by Thomas Blanchard after a fire destroyed his gunstocking equipment in 1825 (Chapter 7; Figure 4.1). As we outline below, Armory managers made repeated improvements of existing Watershops power facilities into the early 1850s, but could not overcome the basic hydrological limitations on their mechanical operations.

These limitations significantly affected the first six decades of Armory operations. The constraints of Mill River topography and power resources made it impossible to consolidate the Armory plant at one site, enforced a permanent separation of the Hill and Water shops, and diffused operations among four principal, geographically separate sites. Similar operations were often housed in different shops at different sites. Given the numerous components and operations required for small arms manufacture, dispersal of operations created considerable transport requirements among shops, and made any rationalized flow of operations impossible. Insufficient water power was probably also responsible for delayed introduction of some mechanical improvements. The net effect of Armory siting was a long-term ceiling on productivity -- despite the best efforts of mechanics and managers -- which was not overcome until the introduction of steam power and enlarged shops in the 1840s and 1850s.

The extra expense and inconvenience of these arrangements were apparent to arms makers when the Armory began operations. Inflating geography somewhat, Eli Whitney remarked that:

"...after viewing the works at Springfield where their waterworks are at some distance from the principal Armory, I ...determined to do all my work at one spot. The Super-intendent at Springfield told me that it would cost 4,000 dollars more to do the same in 2 places two miles distant from each other, than if it were all concentrated in one place."[407]

[406] Ibid.

[407] Whitney to Wolcott, May 1, 1798. Eli Whitney Papers, Yale University Library.

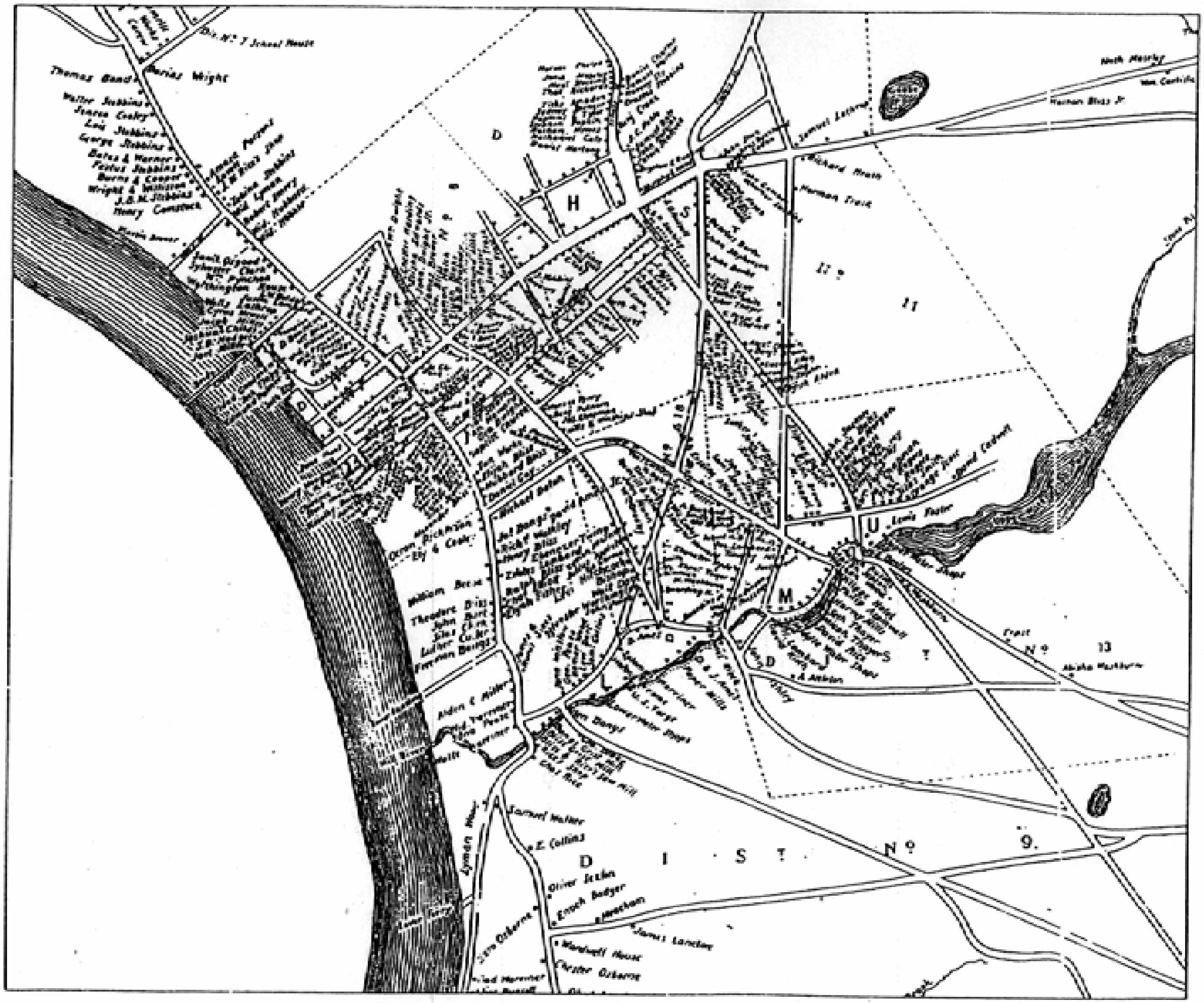

Figure 4.1 MAP OF SPRINGFIELD, MASS., 1835, WITH SPRINGFIELD ARMORY LOCATIONS ON ARMORY HILL (H) AND UPPER, MIDDLE, AND LOWER WATER SHOPS (U, M, L) ON MILL RIVER

Source: George Colton, Map of Springfield, 1835, reproduced in Mason A. Green, Springfield 1638-1886, History of Town and City

Table 4.1. SPRINGFIELD ARMORY BUILDING CONSTRUCTION FOR ARMSMAKING AND STORAGE, 1794-1855[14]

Period	Hill Shops	Lower Watershops	Middle Watershops	Upper Watershops
1794-1798	2 2-story frame arsenals, each 100x25 feet; 1 forging shop, 160x34 feet; 1 1-story "air furnace" building, 51x30 feet, inside the square; 2 1-story filing shops, 95x15 & 64x19 feet, inside the square; 1 1-story carpentry shop, 80x20 feet, inside the square; 4 charcoal houses, inside the square; proof and musket barrel proof houses	"old shop," 52x30 feet; "new shop," 50x40 feet; 2 charcoal houses	poorly documented	------------------------------
1801-1805	Fire destroyed 1 filing shop, 1801; replaced by use of barracks	Fire destroyed "main shop," 1805; replaced in wood & stone, 88x60 feet with forge	poorly documented	------------------------------
1807-1809	2-story brick [West] arsenal, 100x34 feet; 2-story brick shop, 204x32 feet, for stocking, filing, & lock finishing, at north end of present Bldg. 16; 1-1/2-story brick forging shop at northeast corner of square, 130x32 feet, for lock parts, pins, ramrods, & tool repairs; brick annealing shop, 35x15 feet, southwest of new forges; brick file cutting [?] shop, 20x15 feet, northwest of new forges	2-story brick & stone shop, 55x32 feet, north side of river	poorly documented	2-story brick & stone "polishing shop," 65x32 feet on north side of river; 1-story stone welding shop, 75x30 feet on south side of river

Table 4.1. SPRINGFIELD ARMORY BUILDING CONSTRUCTION FOR ARMSMAKING AND STORAGE, 1794-1855 (cont.)

Period	Hill Shops	Lower Watershops	Middle Watershops	Upper Watershops
c1809-17	1 carpentry shop; 1 charcoal house	sawmill site purchased above, 1817; use unclear to 1825; used by Blanchard after 1825 fire	1-story stone welding shop, 80x49 feet; 1-story stone tilthammer shop, 50x25 feet; carpenter's shop, 115x15 feet; 4 charcoal houses	1-story brick annealing shop, 32x15 feet; 4 charcoal houses
1819	2-story brick office/chapel, 34x44 feet, center of present Bldg. 16	scrap iron forge	1 charcoal house burned; fire engine installed	
c1819-24	iron storehouse, 75x15 feet, northeast of forging shop, converted to proof house, loading room, & inspection room c1824-30; unidentified, 100x35 feet, north of forging shop	Blanchard stocking shop c1823		
1824	Fire destroyed stocking & filing shop; replaced same site by 2-story brick bldg., 135x15 feet--"North Workshop"; 2-story brick filing/assembling shop, 135x35 feet--"South Workshop"--south end of present Bldg 16.			
1825	2-story brick (East) arsenal, 120x35 feet; old frame arsenal here moved across street	Fire destroyed Blanchard shop		
1826		2- & 3-story brick stocking shop, 65x40 feet		

Table 4.1. SPRINGFIELD ARMORY BUILDING CONSTRUCTION FOR ARMSMAKING AND STORAGE, 1794-1855 (cont.)

Period	Hill Shops	Lower Watershops	Middle Watershops	Upper Watershops
1828-1829		brick & stone rolling mill-forge complex, 63x50 & 33x29 feet		1-story frame iron store & inspector's room, 29x18 feet
c1824-30	frame fire engine house, 34x16 feet, southwest of forge shop; coal house, 60x35 feet, north of forging shop; 2 frame carpenters shops, 28x18 & 40x18 feet (latter with 23x16 addition); pit-coal bin, 17x11 feet; sand house, 10x6 feet	2 iron storehouses: 24x18 feet & 20x15 feet (scrap iron?) 1 blacksmith shop, 25x12 feet; 3 coal houses, 30x24, 51x25, & 30x30 feet; 1 anthracite & pit-coal house, 30x14 feet	1 coal house, 70x35 feet; 1 iron storehouse, 20x16 feet	new 2-story brick North Shop, 94x40 feet; 2 coal houses, 60x30 & 25x25 feet; 1 old leather storehouse, 20x15 feet
1830	3-story brick Middle Arsenal, 121x41 feet			
c1831-34	frame hook-and-ladder house, 38x15 feet	brick annealing house, 22x14 feet		
1836-1837			rebuilding program; limited documentation	
1843-1845	2-story brick "new machine shop," about 90x32 feet attached northeast of forging shop, with steam engine; MWS & UWS milling machines moved to old forging shop		new tilt hammers	grinding room rearranged to take LWS grinding machinery
1845-1846	2-story brick machine shop extension, 61 feet to northeast, used in part for stocking machinery	-----OPERATIONS CEASED-------	flume improvements	

Table 4.1. SPRINGFIELD ARMORY BUILDING CONSTRUCTION FOR ARMSMAKING AND STORAGE, 1794-1855 (cont.)

Period	Hill Shops	Lower Watershops	Middle Watershops	Upper Watershops
1846-1847	3-story brick Main Arsenal begun, 198x67 feet, completed 1849-1850; brick storehouse for stock & lumber storage begun, 400x55 feet, completed by 1850	----------------------------	roof of rolling mill & welding shops raised for ventilation & light	
1847-1848	remodelling of part of machine shop for improved annealing furnace and vitrioling work	----------------------------	welding shop chimneys removed, & more roof work	improved barrel annealing furnaces
1848-1849	cast iron forges replaced brick forges	----------------------------	cast iron forges replaced brick forges	cast iron forges replaced brick forges; rearrangement of machinery to make barrel operations contiguous
1849-50	Filing transferred to machine & stocking shop from South Workshop, which was then used for musket conversion; new fire engine house; 700,000-gal. brick cistern north of machine/stocking shop	----------------------------		fan blower and conductor added to polishing shop for dust-free workspace
c1845-50	proof house, about 20x20 feet, north of machine/stocking shop; 2 store houses, each about 75x40 feet, north of machine/stocking shop			
1851-52	gas lighting first installed			
1855-56		---------SITE SOLD-----------	------SHOPS DEMOLISHED---------	MOST SHOPS DEMOLISHED, SITE WORK BEGUN FOR NEW WATERSHOPS COMPLETED 1859-1860

*Sources for figure 4.1 and table 4.1: Whittlesey; ARSA 1845 1845-59, in RG 156/1354; "Plan of Land sold to the United States in Springfield and the public Buildings standing thereon/1801"; "A Return of all Publick Buildings at Springfield, Mass. with their Dimensions and estimated Value. September 1798"; "A Description of the united States Armory at Springfield . . . to the close of the year 1817"; Thomas B. Linnard, "Map of Springfield Hill . . 1824", "A Plan of the Public Land in the Town of Springfield [1830]", "Armory Hill [1830]", "A Plan of Land about the Middle and Upper Water Shops [1830]"; U.S., Congress, House, Superintendents of National Armories . . ., pp. 149-60.

B. Dispersed Plant Improvements and Operations, 1794-1843

Construction of Shops, Storehouses, and Arsenals

The Armory began operations with the workshops and barracks of the earlier arsenal, to which were soon added the first improvements at the Lower Watershops and a few additional shops on the Hill. The Hill Shops encompassed all forging, filing, stocking, and assembly operations, and probably some finishing tasks on small metal components. Water-powered grinding, polishing, and perhaps some turning operations, along with hand- and water-powered barrelmaking, took place on the river. By 1798, there were about a dozen frame shops and arsenals on the Hill, and two frame shops at the Lower Watershops. The Hill Shops, in and around what became Armory Square, included two arsenals on the south side of the quadrangle, and a forging shop along the north half of the past side. Some workers and managers lived in houses on the north side.[408] Although most of the shops were inside the quadrangle, the use of the east side for manufacturing and the south side for arsenals persisted until the end of the 19th century.

Table 4.1 and Figure 4.2 summarize construction activities and the general distribution of Armory manufacturing activities prior to the introduction of steam power c1843. This was the period of maximum dispersal of operations. At best, different tasks or processes were organized in separate shops, but, as noted above, waterpower limitations often precluded discrete separation of tasks by shop. Several general patterns of construction reflect the concerns and plans of Armory managers, notably superintendents Benjamin Prescott (1805-1813) and Roswell Lee (1815-1833). Following fires in 1801 and 1805, Prescott replaced virtually all Armory structures in stone and brick, and enlarged the number and size of many shops. He oversaw the acquisition and construction of the

[408] "Plan of Land sold to the United States in Springfield and the public Buildings standing thereon/1801," SANHS; "A Return of all Publick Buildings at Springfield, Mass. with their Dimensions and estimated Value. September 1798." National Archives, Records of the Adjutant General's Office, Record Group 94. We are indebted to SANHS historian Larry Lowenthal for showing us the latter document.

Upper Watershops, and removed or demolished all frame structures inside the Armory Square quadrangle. Lee, who contended with two major fires in 1824 and 1825, continued a similar plan of brick and stone expansion, particularly as he introduced more mechanized operations at the Watershops. Lee gave special attention to construction of storage facilities, allowing greater control of raw material costs (Chapter 5), and to firefighting equipment.

Waterpower Development and Fragmented Operations

With a drainage basin of about 33 square miles, Mill River's mean flow is about 64 cubic feet per second, as estimated from hydrological data.[409] The 1795 purchase on the river included the right to build a dam 5.5 feet high.[410] Information on the chronology and waterpower facilities of the Armory watershops is very limited, but if we assume that a dam with the full allowed height was constructed, the theoretical mean power available at the site would have been about 36 horsepower at mean stream flow.[411] 1795 purchases of six tons of iron frames for water wheels suggest immediate construction at the first watershop, where shortly thereafter two shops operated with trip hammers and, probably, power-driven grindstones and polishing discs.[412] Sometime before 1799 two lathes were in place, probably used for turning breech plugs.[413] It was soon apparent that the available power was inadequate for the work to be done with this machinery, and the other watershops sites were gradually acquired. At least one of the upper two watershops sites was purchased with the right to build a 10-foot-high dam.[414] Documentation of waterpower improvements in the period before 1843 is incomplete, but the pattern of limits to Armory productivity emerges clearly in available data.

Roswell Lee initiated a period of rapid expansion in Armory mechanization soon after his arrival at Springfield (Chapter 7). Asa Waters had started using trip hammers with semicircular dies for barrel

[409] Robert B. Gordon, "Hydrological Science and the Development of Waterpower for Manufacturing," pp. 217-18.

[410] Whittlesey, Appendix 3.

[411] Gordon, pp. 217-18.

[412] Springfield Armory Journals of Receipts and Expenditures, 1794-1811, RG 156/13.

[413] Felicia J. Deyrup, Arms Makers of the Connecticut Valley, p.35. We are indebted to arms collector and historian Lennox Beach for the suggestion on the use of the early lathes.

[414] Whittlesey, Appendix 3.

welding at his works in Millbury in 1808 or 1809,[415] a technology Lee transferred to Springfield, first with one hammer in 1815. By 1816, four trip hammers for barrel welding operating at 400 blows per minute were in place at the Middle Watershops. They were driven by a wheel described as made on Tyler's plan with a perpendicular shaft, which Lee believed used only 1/2 to 2/3 as much water as an undershot wheel that would do the same work.[416]

In the summer of 1822, Lee replaced the wooden dam at the Upper Watershops with a substantial stone dam, optimistically reporting that "It is a permanent work and will remain as long as the United States have occasion to make arms."[417] By 1824, the armory was using 27 wheels at the three watershops, with a drive system that permitted several trip hammers to be run independently off one wheel. Even with the new dam, the flow of water was found to be inadequate to sustain the level of production attained by that time, and Lee was interested in the possibility of obtaining more power through the higher efficiency of reaction wheels and in the use of steampower.[418] A report prepared in 1830 listed 13 tub, 6 undershot, 7 breast, and 1 low breast wheels in use.[419] Although it did not indicate in which shops the different wheels were located, or how many of the 27 wheels were the same as those used in 1824, it is apparent that Lee had made only moderate progress in modernizing the power generating equipment. Nineteen of the 27 wheels noted in 1830 were the relatively inefficient tub and undershot types. The 27 wheels in 1830 were said to use about 268 cubic feet per second of water. The product of flow times fall for each wheel was also reported and, if the aggregate efficiency of the 27 wheels were 50%, they would have generated 73 horsepower. The Mill River valley is narrow, little storage of water in ponds would have been possible at any of the water shops, and the wheels would have been operated in the run-of-river mode. If distributed so as to consume the same amount of water at the three principal watershop sites, the 27 wheels would have required a stream flow of 89 cubic feet per second. Since the mean flow of the river was about 64 cubic feet per second, there would have been enough water to operate all of the Armory's

[415] Lee to Bomford, June 27, 1818, RG 156/1351.

[416] Lee to Wadsworth, December 24 1816, RG 156/1351.

[417] Lee to Bomford, August 21, 1822, RG 156/1351.

[418] Lee to Whitney, July 19 1824, RG 156/1351.

[419] <u>American State papers, Class V, Military Affairs</u>, 4: 491.

machinery during less than about a third of the year.[420] This may be one reason that the pace of mechanization slowed after 1821.

Between 1830 and 1854 -- when the Watershops were consolidated at the upper site -- data on Armory improvements indicate that more wheels were added:[421]

Year	1830	1834	1835	1836	1838	1841	1842	1843	1845	1846	1848	1851	1853
# wheels	1	1	1	2	2	1	1	5	3	1	1	1	1

Since there was already a shortage of water to operate the 27 wheels in place in 1830, it is likely that most of these additions were replacements of more efficient types for older, less efficient wheels. Additionally, a dam was built at the Middle Watershops in 1835 and a flume in 1837. An unspecified number of wheels were "improved" in 1847.[422] There was, then, continuing concern with the development of the limited waterpower resources available to the Armory throughout this period.

Waterpower constraints not only resulted in less efficient mechanization of individual operations, but dispersed operations and increased transport costs among Armory shops. Table 4.2 presents the chronological and spatial distribution of most Watershops operations prior to the introduction of steampower. In some periods, identical operations were conducted at different Watershops, although Roswell Lee appears to have managed consolidation of most individual operations in single shops by c1820. The need to move components between operations remained a less tractable problem. For example, barrelmaking c1830 included drawing or rolling of the skelp, welding, nut boring, and counterboring at the Middle Watershops, transfer to the Upper Watershops for smoothboring, turning, milling, straightening, grinding, vent drilling, and polishing, and transfer again to the Hill finishing shop for browning (see Chapter 7).

For small lock components, forged on the Hill, transfers increased. A tumbler c1830 went from the

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[420] Gordon, "Hydrological Science..'" p. 218.

[421] Superintendents of National Armories..., pp. 148-60.

[422] Ibid.

forge shop to the Upper Watershops for facing and milling, to the Lower Watershops for drilling, and up to the Hill filing shop.[423]

Table **4.2.**

MANUFACTURING OPERATIONS AT SPRINGFIELD ARMORY WATERSHOPS, 1808-1843[424]

Component & Operation		Power	Period	LWS	MWS	UWS[425]
Barrels:	cutting skelp	water	c1808-20		x	x
			c1820-25		x	
	drawing skelp	water	c1808-16		x	x
			c1816-30		x	
	rolling skelp	water	c1815-43		x	
	welding	hand	c1808-16		x	x
		water	c1816-43		x	
	nut boring	water	c1808-35		x	
			c1835-43			x
	counterboring	water	c1814-20		x	
			c1820-25			x
			c1825-35		x	
	smoothboring	water	c1808-15		x	
			c1815-20		x	x
			c1820-43			x

[423] Springfield Armory Work Returns, January 1830, RG 156/1371; C. Meade Patterson, "Musket-Making Operations at Springfield Armory in 1825."

[424] Sources: Springfield Armory Work Returns, 1808-1814, 1816, 1820, 1825, 1830, 1835, 1840, 1843, RG 156/1371; Lee to Calhoun, January 13, 1825, as presented in Patterson; also see Chapter 7 of this report. Work returns for 1808-14 were sampled for month of February, later years for January; returns prior to 1808 were generally incomplete or absent. Since there were probably seasonal fluctuations in watershops work and products, absence of a particular operation at a shop in one month sampled does not necessarily mean the shop was not responsible for the operation, if bracketing sample months show the same operation at the shop. A few assumptions about continuity of operations were therefore necessary. Some operations in the work returns which were ambiguously described, or were apparently done at the watershops only very occasionally, were omitted. It is possible the latter represent work done by armorers who, while usually working in one shop, performed limited amounts of work in other Armory shops; in such cases, credit for the work would probably appear on the work returns for the 'usual' shop.

[425] LWS = Lower Watershops; MWS = Middle Watershops; UWS = Upper Watershops

	turning	water	c1820-43			x
	milling	water	c1811-20		x	
			c1820-35		x	x
	cutting breeches	hand	c1810			x
			c1811-13		x	
	milling breeches	water	c1835-43			x
	milling squares for studs	water	c1835-43			x
	straightening	hand	c1825-43			x
	grinding	water	c1808-15	x	x	x
			c1815-43			x
	drilling vents	water	c1814-43			x
	polishing	water	1808		x	
			1809	x		
			1810-43			x
Bayonets:	forging	hand	c1808-25		x	
			c1825-35		x	x
	swedging	hand	c1835-43		x	
	boring socket	water	c1811-16		x	x
			c1816-43			x
	turning socket	water	c1816-43			x
	milling socket	water	c1820-43			x
	weld socket	water	c1840-43		x	
	grinding blade	water	c1809-16	x		x
			c1816-43			x
	grinding flute	water	c1820-43			x
	polishing	water	c1811-43			x
Ramrods:	drawing	water	c1816-30		x	
	rounding	water	c1820-43		x	
	milling heads	water	c1835-43			x
	straightening	hand	c1813-43			x
	grinding	water	c1808-43	x		
	polishing	water	c1810-20			x
			c1820-25	x		x
			c1825-43			x

Upper& Lower Bands:	cutting	water	c1820-43	x		
	forging	hand	c1835-43	x		
	filing	hand	c1820-43	x		
	grinding	water	c1808-10	x		
			c1810-20	x		x
			c1820-43	x		
	polishing	water	c1820-35	x		
			c1840-43			x
	drilling (upper)	water	c1825-43	x		
Middle Bands:	forging	hand	c1808-43	x		
	filing	hand	c1815-35	x		
	grinding	water	c1808-10	x		
			c1810-20	x		x
			c1820-43	x		
	riveting swivel	hand	c1820-35	x		
Swivels:	polish	water	c1811-35			x
Guards:	forging plate	hand	c1808-15	x		
			c1815-25		x	
			c1825-35	x		
	milling plate	water	c1825-35	x		
	trimming plate	water	c1825-43	x		
	filing plate	hand	c1815-35	x		
	drilling plate	water	c1820-35	x		
	countersinking plate	water	c1820-25	x		
	forging bow	hand	c1825-30		x	
	milling bow	water	c1825-30	x		
			c1830-35	x		x
	grinding, drilling bow	water	c1835	x		
	filing bow	hand	c1820-43	x		
	grinding (riveted) guard	water	c1810-12			x
			c1812-43	x		

polishing (riveted) guard		water	c1825-30	x		
			c1835			x
finishing (riveted) guard			c1825-43			x
Triggers:	forging	hand	c1808-12	x		
	trimming	water	c1825-30	x		
	milling	water	c1835-43			x
	filing	hand	c1815-20	x		
			c1820-43			x
Band Springs:	forging	hand	c1808-16	x		
	filing	hand	c1815-35	x		x
Breech Plates:	forging	hand	c1808-20	x		
(butt plates)			c1820-43		x	x
	trimming	water	c1835-43	x		
	punching	water	c1825-35	x		
	countersinking	water	c1820-30	x		
	filing	hand	c1825-43	x		
	grinding	water	c1809-30	x		x
			c1830-43	x		
Trigger Pins, Side Screws Tang Screws, Breech Plate Screws, Guard Screws, Cock-pins, Lock-pins:						
	slitting, milling	water	c1811-43			x[426]
	cutting	hand	c1811-43			x

[426] Armory work returns show the Upper Watershops as "cutting screws" and "slitting and milling pins and screws" from c1811-1843. Even though the chronology of machine operations on specific types of screws is incomplete, it is clear that the Upper Watershops did all such operations.

Lock Plates:	grinding	water	c1808-20	x		
			c1820-43			x
	milling	water	c1840-43			x
	drilling	water	c1815-43			x
Hammers:	drilling	water	c1815-30			x
Brass Pans:	boring	water	c1820-43			x
	drill & mill	water	1843			x
	anneal	hand	c1840-43			x
Cocks:	milling	water	c1835			x
	drilling	water	c1816-43	x		x
Tumblers:	facing	water	c1830			x
	milling	water	c1811-43			x
	drilling	water	c1820			x
			c1820-30		x	
Bridles:	drilling	water	c1816-35			x
Sears:	drilling	water	c1816-43	x		x
	milling	water	c1830-43			x
Locks:	polishing	water	c1808-10	x		
			c1810-12	x		x
			c1812-43			x
	hardening	hand	c1825-43			x
Main Springs: mill, drill, & polish		water	c1830-43			x
Hammer Springs:	drilling	water	c1820-43			x
	milling	water	c1843			x
	polishing	water	c1825-43			x
Sear Springs:	drilling	water	c1814-35			x
Stocks: mechanized operations		water	1823-43	x[427]		

[427] Stocking shop moved to sawmill site, above Lower Watershops, during 1825-26 rebuilding of burned shop.

OTHER UNSPECIFIED OPERATIONS:

"Plates":	cutting	hand?	c1825-30	x	
	grinding	water	c1813-16		x
			c1816-35	x	
			c1835-43		x
	polishing	water	c1813-43		x
"Mountings":	punch	?	c1808-13	x	
	drill	water	c1808-13	x	
	straighten	water	c1808-13	x	
	mandril	hand	c1808-13	x	
	filing	hand	c1808-13	x	
	polish	water	1808-16	x	x
			1816-43		x

C. Steampower and Expanded, Consolidated Operations, 1843-1860

Roswell Lee considered the possibility of using steam power at the Armory in the 1820s, and some experiments with steam power were made at the Armory beginning in the 1830s, but only in 1843 did Maj. James Ripley contract for the first engine used in regular production. The context of Ripley's decision is not fully documented, but must have included preparation for manufacture of the M1842 musket with a larger number of milling machines (see Chapter 7). Construction and operation of more milling machines required more power than the Armory had ever used before, and increased use of the Mill River was clearly out of the question. The arrival of railroads in Springfield in the early 1840s lowered the costs of coal, with which we presume the engine's boiler was fired, and made the conversion more feasible. Ripley's ambitious program of new construction and consolidation of shops, completed c1843-50, began with installation of the 30 hp steam engine in a new machine shop next to the Hill forging shop.[428] The engine provided both power and heat.

[428] This engine was built by Otis Tufts of Boston, under a contract dated June 10, 1843, RG 156/1382. The contract called for it to be similar to the one Tufts built for the Charlestown Navy Yard, with two cylinders of 9 inch bore and 30 inch stroke, slide valves with adjustable cut- off, and Tuft's expanding eccentrics. The piston rods were to be of cast steel and the cylinders encased in wood. The fly wheel, eight feet in diameter and 13 inches wide, was to weigh 1,500 pounds and the journals for the shaft to be four inches in diameter and ten inches long. The engine was to be mounted on a cast iron frame 13 feet 10 inches long and 8 feet wide. The contract called for a single flue boiler, 6 feet long by 42

By quickly expanding this new facility, and moving into it all milling and stocking machines from the Mill River shops by 1846, he was able to transfer all remaining Lower Watershops operations to the Upper Watershops and close the lower site. Other major improvements in this period included the Main Arsenal, a long stock storage building north of Armory Square, and a large cistern north of the machine-stocking-forging shop complex for firefighting and steam engine use (Table 4.1, Figure 4.3).[429] Ripley also continued to make improvements to the Middle and Upper Watershops until 1850, by which time his work had expanded the Armory's manufacturing capability. A former master armorer, Joseph Weatherhead, credited Ripley's improvements with increasing the capacity of the Armory from 15,000 to as much as 25,000 arms per year.[430]

The waterpower situation evidently remained unsatisfactory, however. Shortly before his plans were curtailed by the controversy over military superintendency of national armories (Chapter 2), Ripley considered moving all shops to the Hill for steam-powered operation.[431] His successor, James Whitney, reviewed this same option, but in 1855 decided to rebuild all the water-powered facilities at the Upper Watershops. With War Department concurrence, he spent much of the next five years on this large project.[432] The work included raising the dam 10 feet, excavating three turbine wheel pits, and building a complex of forging, barrel- and scrap-rolling, and barrel-finishing shops north of the river (see Chapters 5 and 7 on barrel rolling). The brick and stone shops included a front finishing shop 200 by 52 feet, and a forging shop about 332 by 62 feet (Figure 4.3). Two turbines and a center vent water wheel, installed by 1858 with an estimated combined 140 hp, powered all Armory forging and barrel-making operations when the new shops were completed in 1860. With removal of forging from the Hill shops, additional consolidation there allowed for polishing and filing of all smaller metal parts in the machine shop complex at the northeast corner of Armory Square.[433] Whitney's work thus eliminated some trips among shops, and all components traveled

inches diameter, with a maximum operating pressure of 150 pounds per square inch.

[429] ARSA 1845-50, in RG 156/1354.

[430] Superintendents of National Armories...

[431] Ripley to Craig, October 8, 1852, RG 156/1351.

[432] Whitney to Craig, November 17,1854, and Whitney to Alger, March 24, 1855, RG 156/1351; Craig to Davis, June 29, 1855, RG 156/5.

[433] ARSA 1855-60, in RG 156/1354.

only once from the new Watershops to the Hill for milling and filing prior to final assembly.

D. Civil War Expansion and Post-War Quiet, 1861-1888

The Ripley and Whitney years left the Armory in excellent condition to meet the production challenges of the Civil War. At the new Watershops, Commandant Alexander Dyer needed only modest additions. He expanded the forging and grinding areas during the first year of the war, and for the first time installed steam power at this site to meet heavy wartime demands.[434] The 150 hp engine was apparently replaced with a 200 hp engine by June 1863.[435]

On the Hill, where much new machinery was installed (see Chapter 7), Dyer intensified the use of the existing shops with additions and refitting of older buildings (Figure 4.4). During the first year of the war, he converted all three arsenals on the south side of Armory Square for manufacturing, adding third stories to the East and West arsenals for respective use as assembling and finishing shops, and mechanizing the Middle Arsenal as a stocking and rifling shop with a 60 hp Corliss engine. The three two-story structures on the east side of the square were combined as a single three-story building, used for milling and filing, in the same period. Use of the arsenals allowed for expanded milling, polishing, and tempering operations in the pre-war machine shop at the northeast corner of the square. By June 1863, Dyer increased the facilities there for annealing, tempering, and case hardening, and added at least one 60 hp steam engine.[436] He also erected a row of buildings to the north for stock drying, machine forging, and blacksmith work, and greatly extended the stock blank storehouse begun in the 1840s. Early in 1864, the Armory received a large amount of new machinery (Chapter 7), some of which Dyer accommodated with a new two-story, 225x35-foot addition to the milling Shop complex stretching north along Federal Street. This structure, powered by another steam engine at the north end, housed a machine shop, a carpenter shop, and a pattern shop.[437] One apparent effect of Dyer's wartime work was greater rationalization of shop

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[434] Dyer to Ripley, October 24, 1861, RG 156/1351; ARSA 1862.

[435] G.B. Prescott, "The United States Armory;" ARSA 1863; Shedd and Edson, "Plan of Land with the Water Shops, belonging to the Springfield Armory, Springfield, Mass. April 1864," SANHS.

[436] The original 1843 30 hp engine may have remained through the war, or another 30 hp engine may have replaced it.

[437] ARSA 1862, ARSA 1863; Shedd and Edson, "Topographical Plan of the Springfield Armory, Springfield, Mass. April 1864," SANHS.

arrangements, with spatial arrangements more closely matching the order of production. It is not clear how much plant arrangements added to the enormous increases in output during the war, when nearly 3000 men sometimes worked at the Armory.

The period between the Civil War and the earliest preparations for magazine rifle production was one of limited Ordnance Department funding and a superfluity of wartime facilities and equipment (Chapters 1 and 2). The arsenals on the south side of Armory Square were returned to storage, with the West Arsenal becoming an Officers' Quarters in 1877. Aside from minor improvements and refurbishing projects, the only notable Armory plant additions were the construction and outfitting of a firing house for small arms experiments (c1872; see Chapter 8) and the construction of office wings on the front tower of the Watershops in 1884.[438] The firing house was built east of Armory Square, in an eighteen-acre tract across Federal Street purchased from the Town of Springfield in 1812.[439] It was in this almost empty space known as Federal Square and long reserved by the government that the next generation of plant improvements began.

E. The Earliest Armory Magazine Rifle Plant, 1888-1898

As the lengthy process for selection of an Army magazine rifle came to a head in the late 1880s, Armory commandant A.R. Buffington realized that the Hill shops in Armory Square -- some nearly eighty years old -- were susceptible to fire. Anticipating relatively imminent production of a new rifle, the Ordnance Department approved Buffington's plans for a completely new plant in Federal Square by June 1888. Displacing the firing house of the 1870s, contractors erected a three-building complex facing Federal Street between 1888 and 1894.[440]

Design changes and the gradual reorganization of shops for Krag rifle production prolonged completion of the complex. Each brick structure had two stories and a high basement, and was regarded as fire-resistant with cast-iron columns, iron stringers and floor joists, and brick-arch

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[438] SFSA 1870-1884; Shedd & Edson, "Topographical Plan of the U.S. Armory. Springfield, Mass. Feb. 1877," SANHS; Article of Agreement between Frank S. Parkhurst and A.R. Buffington, August 1, 1884, RG 156/1382.

[439] Whittlesey, Appendix 3.

[440] ARSA 1889, in ARCO 1889 pp. 355-56.

floors. The north and south buildings, each 279 by 36 feet, respectively housed the milling and carpenter/stocking shops. The central building, 458 by 36 feet with wings to east and west, served principally as a machine and filing shop (Figure 4.5). The north and south wings of this building, along with other sections, were designed for blacksmith and forging work, annealing, case hardening, inspection, polishing, assembly, test firing, and offices and drafting space of the master armorer. Until the 1893 installation of a new power plant in the center of the machine and filing shop, the partially complete complex was powered, via shafting through tunnels, by the older engines in the Armory Square machine and filing shops. The new power plant consisted of two 150-hp Corliss engines and four Babcox & Wilcox boilers, and was anticipated to have far more capacity than immediately needed for power and heat.[441]

The new plant was more compact than the Armory Square shops -- which were converted to storage -- and included some improved facilities, notably the larger power plant, electric lighting, elevators, and extensive exhaust systems in the stocking, carpentry, forging/blacksmith, polishing, and browning shops.[442] The blacksmith shop, which took several years to complete, apparently replaced the Watershops for forging of some smaller metal components, further consolidating rifle manufacture. Although filled with specially adapted milling equipment for production of the new rifle (Chapter 7), the Federal Square shops evidently did not provide much additional armsmaking capacity, having been designed to serve a small Army. Together with the aging Watershops, which had received no improvements of any consequence since the mid-1880s, Armory facilities in 1898 were not well-adapted to rapid expansion for the Spanish-American War. Wartime work included rapid purchase of more machinery, much of which was installed in hastily-floored Federal Square basements. At the Watershops, new equipment required extensive changes in line-shafting and belt transmissions, and greatly strained the capacities of the three water Wheels or turbines (apparently the ones installed in the 1850s) and two 70 hp steam engines.[443] In response to the problems of 1898, there was extensive rebuilding of the Watershops, followed by improvements of other plant

[441] ARSA 1893, in ARCO 1893, pp. 197-99.

[442] ARSA 1894, in ARCO 1894, pp. 51-2; ARSA 1895, in ARCO 1895, pp. 61-2.

[443] It is not clear if the Watershops steam engines of 1898 dated to the Civil War; the stated capacities do not match those given for engines installed in the 1860s, but no engines are positively known to have been installed prior to 1899.

components.[444]

F. Modernization and Plans for More Efficient M1903 Production, 1898-1919

The determination of Armory managers not to enter another crisis with outmoded facilities led to a five-year program of Watershops improvements. New power systems installed at the Watershops made the relatively recent Federal Square shops appear inefficient by comparison, spurring further changes on the Hill. As the second round of magazine rifle plant development unfolded after 1900, there was increased attention to lower production costs and greater productivity, stemming in part from the Ordnance Department's concerns about its control of Army procurement (Chapter 2). Armory managers, influenced in part by Taylorist planning or material control systems, made extensive efforts to streamline and rationalize operations c1902-12. Perhaps the largest such project was the 1908-15 introduction of rail and trolley lines between the Hill and Water shops, and between each of the shops and trunk line connections, to alleviate some of the century-old transportation problems created by original Armory siting. However, the constraints of Army funding did not allow for translation of these efforts into a rifle plant of a scale needed for World War I.

Watershops Addition and Improved Power Systems

Improvement of antiquated or inefficient power and transmissions systems was a persistent concern during this period, emerging from the post-1898 Watershops improvements. Initial upgrading of the Watershops after the Spanish-American War followed older patterns: installation of still larger steam engines and turbines, and strengthening of inadequate flooring or structural members. The new waterpower equipment included a 300-hp condensing steam engine, and two turbines with a combined 342 hp.[445] By 1900, the need for increased testing and production equipment to handle magazine rifle steel barrel requirements (see Chapters 5, 7, and 8) apparently stimulated a significant expansion of the Watershops, where a 256-foot-long extension of the front shops was erected over the Mill River from 1900 to 1902 (Figure 4.6). During the course of this project, three 170 hp Babcox & Wilcox boilers were added to the power plant.[446]

[444] ARSA 1898, in ARCO 1898, pp. 81-4.

[445] ARSA 1899, in ARCO 1899, p. 145.

[446] ARSA 1901, in ARCO 1901, p. 160.

By the time the Watershops addition was complete, however, it was proposed to run the new section with a series of 20-hp electric motors. The background to this important decision remains undocumented, but is of some interest as the earliest stage of Armory electrification of manufacturing. When completed and outfitted in 1903, the Watershops addition had an electric plant run off a new 24-inch turbine, with motors suspended from shop ceilings to drive two separate line-shafts each. The more controlled speeds of electrically-driven line-shafts allowed for several efficient changes in machine tool use at the Watershops, including replacement of rope drives for belting in some drilling operations, and centralized lubricating arrangements in the barrel shop. The electric system compared very favorably with the older steam-engine drives used at Federal Square, where centrally-located steam engines ran long line shafts through three buildings with numerous changes in direction, and by 1907 Armory managers were requesting similar arrangements on the Hill. Once the M1903 rifle was under production and distributed to the Army, however, Ordnance Department interest in Armory improvement waned and the old Federal Square line-shafting remained in place until after World War I. Armory managers actually rebuilt the Federal Square power plant in 1912-14 to install generators driven by boilers and steam turbines, but did not receive funds for the equipment.[447]

Reorganization of Manufacture and Materials Handling

Springfield Armory began rationalizing some Krag rifle shops immediately after the Spanish-American War, anticipating production of what became the M1903 as part of a long tradition of gradual improvements initiated by Armory managers. Shortly after the completion of the new Watershops addition, for example, rearrangement of barrel manufacture in the addition succeeded in confining all such work to the first floor, precluding transfer of barrels to the second story.[448] After about 1906, however, Ordnance Department introduction of some Taylorist methods, amidst the long-standing attention given by Chief of Ordnance, Gen. William Crozier, to department efficiency,[449] almost certainly stimulated some of the numerous steps taken at Springfield to

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[447] ARSA 1901, p.6; ARSA 1902, pp. 1-3; ARSA 1903, pp. 6-10; ARSA 1907, pp. 5-6; ARSA 1909: 16; ARSA 1913: 7-10; ARSA 1914: 5-7; all at SANHS.

[448] ARSA 1904: p.8, SANHS.

[449] Hugh G.J. Aitken, Scientific Management in Action, pp. 49-60.

improve the productivity of plant arrangements prior to World War I.

Aside from improvements in mechanization and other equipment (Chapter 7), there were basically four types of plant reorganization in this period. The first involved consolidating operations, a persistent problem at Springfield. In 1907, Hill and Watershops areas divided responsibilities for bayonet and receiver manufacture, for buttplate assembly and finishing, and for the manufacture of tools, gages, and dies. By 1908, such redundancy was eliminated.[450] Rearranging the sequences of equipment and operations in individual shops was a second and closely related improvement, proving particularly successful in bayonet and barrel manufacture.[451] Introducing centralized controls of job planning, component routing, and materials accounting was a third, and most especially Taylorist, innovation. In addition to creating new lines of authority and recordkeeping systems, the new control methods also required allocating space in the Federal Square machine shop complex for new steel stock rooms, a planning department, and expanded inspection facilities.[452]

The fourth and most costly plant reorganization project, in the period before World War I, was the introduction of rail links to Armory shops for faster and cheaper movement of materials and components. Many generations of horses had hauled raw materials from Springfield's river landings and rail depots to the Armory shops, and made countless trips up and down Walnut Street transferring components between Hillshops and Watershops. In addition, transfers between Hill shops remained a persistent problem into the 20th century, especially after the separation of manufacture in Federal Square and storage of materials, such as gunstock blanks, around the Armory Square property. The limited availability of automobile trucks did not remove the problem. Beginning c1907-08, Armory managers initiated a plan to link the shops with each other, and with the New York, New Haven, and Hartford Railroad, via the Springfield city street railway, after securing approval from the local government. Working with limited appropriations, Armory managers completed a workable system along these lines by 1915. The improvements included new coal and, at the Watershops, steel and oil handling facilities linked directly to rail lines, and a rail

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[450] ARSA 1908, pp. 2-14, SANHS.

[451] ARSA 1910, pp. 1-7; ARSA 1911, pp. 1-9; ARSA 1912, pp. 1-7, all SANHS.

[452] ARSA 1910, pp. 1-7, ARSA 1911, pp. 1-9, all SANHS.

transfer system between the Armory Square stock storehouse and stock drying and manufacturing facilities in Federal Square (Figures 4.6, 4.7).[453]

Limits to Improvements and the Armory in World War I

Except for the Watershops addition and the rail system, most Armory improvements between 1898 and 1917 involved equipment purchase and reorganization of existing facilities. There was little expansion of the plant to accommodate the demands of a large war. After the start of M1903 manufacture, construction of new manufacturing facilities was limited to a small addition at the milling shop and a new stock drying house behind the machine shop complex in Federal Square, and, at the Watershops, a target house southwest of the main complex. For new operations such as production of the M1911 pistol or the M1909 machine rifle, older space was reorganized (Figures 4.5, 4.6, 4.7). The only other significant Armory addition before World War I, an experimental firing range built north of Armory Square in 1907-08, was part of a belated attempt to assess potential semi-automatic rifle designs (Chapter 8).[454] Despite technically impressive gains in manufacture of the M1903 rifle, these limited plant additions contributed to the Armory's inability to produce sufficient numbers of rifles in World War I. Other factors, discussed in Chapters 1, 3, and 7, included the use of extremely demanding manufacturing methods which commercial arms makers could not readily adapt in a crisis.

The Ordnance Department and the Armory were essentially unprepared for the scale of World War I, and little plant expansion was possible during the crisis. Wartime construction included chemical and metallurgical laboratories built north of the Federal Square machine shop to control the quality of manufacturing materials (Chapters 3 and 8), small additions to the milling shop and administration building, and many temporary storage structures rose to handle the expanded volume of production (Figures 4.6, 4.7).[455] Rapid curtailment of military expenses after the war precluded most improvements other than the introduction of somewhat more modern machines secured from wartime contractors (Chapter 7). The need for experimental data on weapons performance and design, aggravated by wartime demands, did allow for construction of a new Experimental

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[453] ARSA 1908, pp. 2-14; ARSA 1911, pp. 1-9; ARSA 1915, pp. 9-12; ARSA 1916, p. 7, all SANHS.

[454] ARSA 1909, pp. 2-14; ARSA 1910, pp. 1-7; ARSA 1911, pp. 1-9; ARSA 1912, pp. 1-7, all SANHS.

[455] ARSA 1918, pp. 3-6, SANHS.

Department facility north of Armory Square (Chapter 8). In the Federal Square power plant, wartime funding for the long-awaited turbine-driven generators remained available long enough to install the equipment in 1919, along with electric motors and new transmission systems. The twenty-six year-old Corliss steam engines, Wilson & Babcox boilers, and heavy main shafts were scrapped in 1919.[456]

G. Waiting for the Semi-Automatic Rifle, 1920-1935

This period was marked by compression and curtailment of operations (Chapter 2), with the principal plant improvements before 1930 being introduction of individual motors for some machines and the installation of a new turbine generator at the Watershops, c1920-21. In another ironic twist to the Armory's long struggle to improve its power systems, the new Federal Square power plant was closed in 1923 as manufacturing diminished, to be replaced for some years by power purchased from local utilities. One early sign of the eventual rebirth of the Armory for M1 production, however, was the replacement of the two coal-fired boilers in the Hill power plant with an oil-burning system in 1932.[457]

H. The M1 Era and Beyond, 1935-1960

Until 1939, commitment of appropriations to the complex re-tooling needed for the M1 generally inhibited much new construction. Plant improvements primarily involved centralization of departmental operations and rearrangement of existing space for the large numbers of incoming machines. With the new rifle ready for production, and enormous infusions of money, this situation changed dramatically between 1939 and 1942, as an essentially new and modern plant arose for the paramount production effort of Armory history.[458]

In Federal Square, construction of an up-to-date "factory type building" to house M1 milling operations was the first significant achievement in this program. Completed in 1940 with reinforced concrete floors and columns, Building 104 provided great strength and rigidity for new machinery.

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[456] ARSA, 1919, p. 4, SANHS; Constance M. Green, "History of Springfield Armory," Vol. II, pp. 16.

[457] ARSA 1920, pp. 3-8; ARSA 1921, pp. 3-6; ARSA 1922, pp. 5-9; ARSA 1923, pp. 3-5; ARSA 1932, p. 16, all SANHS.

[458] ARSA 1936, pp. 8-13; ARSA 1937, pp. 48-69; ARSA 1938, pp. 39-43; ARSA 1939, pp. 32-49 all SANHS.

It was designed to house high-speed, motor-driven machinery. It had space for "the milling shops for all the M1 Rifle Components with the exception of the barrel and stock." Production, already underway at this time, was so critical that the Armory moved 875 machines into the new building "with a production time loss of only 4 hours per machine."[459] New shops for gunstocking and machining, and for heat treating and filing/polishing, soon followed, along with some additions to earlier shops and temporary structures. West of Federal Square, important adjuncts to manufacturing included expansion of the experimental facilities, additions or modifications to storehouses, and a substantial brick complex for vehicle storage and Ordnance Department Field Services requirements (Figure 4.8). At the Watershops, the most dramatic improvement was probably the conversion of the early 20th-century target house southwest of the main complex into a heat treating and forging plant, with Lindberg furnaces. Smaller new shops included those erected south of the river for welding and clip manufacture, and for metal finishing operations. Most other Watershops plant additions were for storage of raw materials and scrap (Figure 4.9). With all these improvements completed within six months of the attack on Pearl Harbor, and the thousands of manufacturing improvements outlined in Chapter 7, the Armory was better prepared for World War II than for any conflict since the Civil War.[460]

World War II essentially ended the history of significant plant construction at Springfield Armory, although there were episodes of shop or laboratory modernization, and some improvements in equipment, until about 1960. In 1951, the Armory finally secured its own railhead on Page Boulevard in Springfield, completing a warehouse there in 1954.[461]

ABBREVIATIONS IN NOTES

ARCO — U.S., Ordnance Department, <u>Annual Report of the Chief of Ordnance to the Secretary of War for the Fiscal Year Ended June 30, ----</u>.

ARSA — Annual Report of Operations at the Springfield Armory. Titles vary, and

[459] ARSA 1941, p.28, SANHS.

[460] ARSA 1940, pp. 43-54; ARSA 1941, pp. 28-30, both SANHS; Green, Vol. II, pp. 200-201.

[461] SAHS 2 September 1945 - 30 June 1951, p. 18; SAHS 1 July 1954 - 31 December 1954, p. 4.

reports appear in different archival sources, as noted.

RG 156/	Record Group 156, Records of the Office of the Chief of Ordnance, National Archives. Record entry number follows slash.
SANS	Springfield Armory Historical Summary for the Period ----, on file at Springfield Armory National Historic Site. These are semi-annual or annual reports covering the years 1951-1965.
SANHS	Springfield Armory National Historic Site. This refers to material held by the National Park Service at Springfield.
SFSA	Statement of Fabrications, Other Work Done.. at National Armory, Springfield, Mass. Titles vary. These records, in RG 156/21, appear to be the only available summaries of annual operations c1865-93.

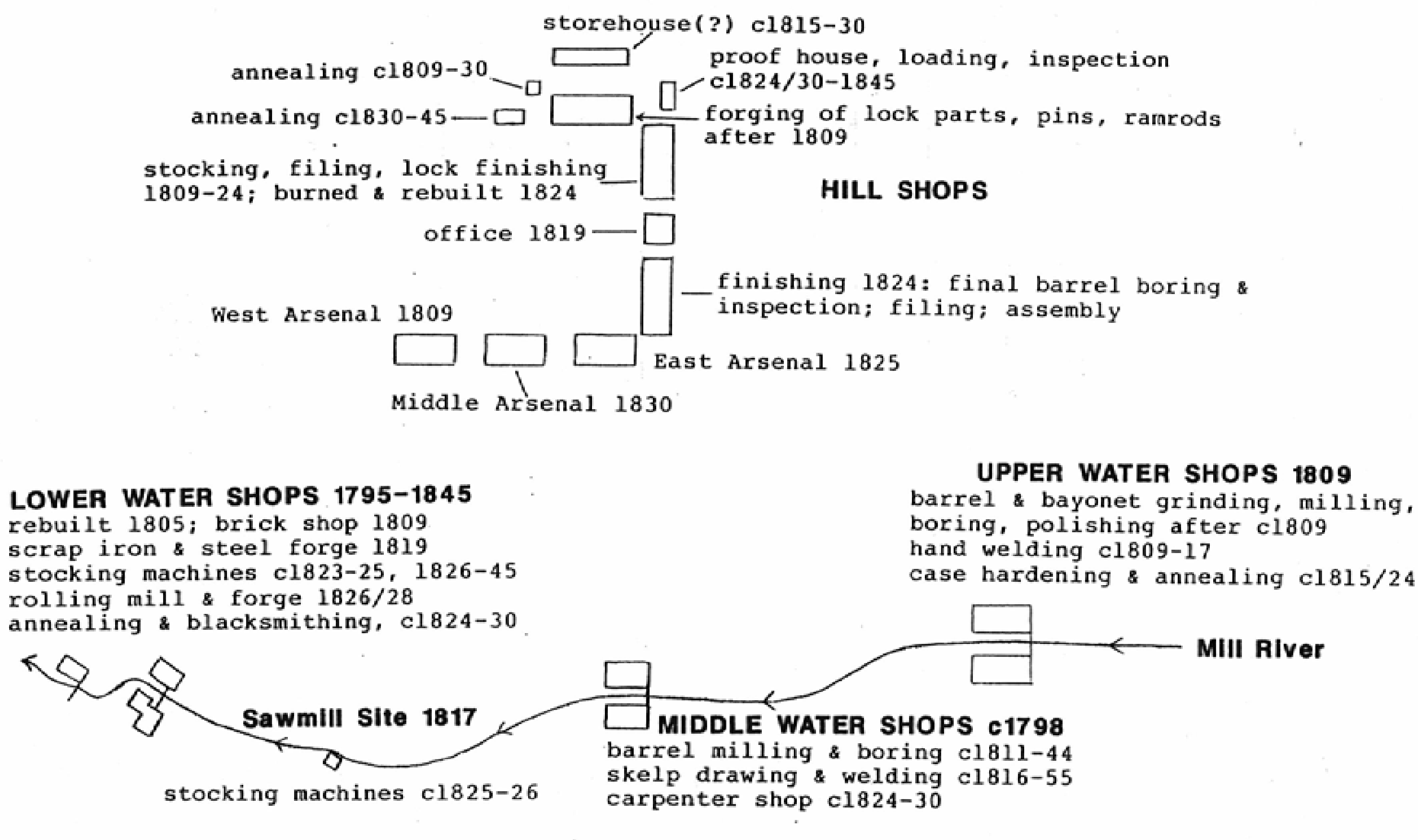


Figure 4.2 SCHEMATIC SKETCH OF SPRINGFIELD ARMORY INDUSTRIAL FACILITIES, c1805-1845
Single dates denote year of construction or start of operation. Not to scale.

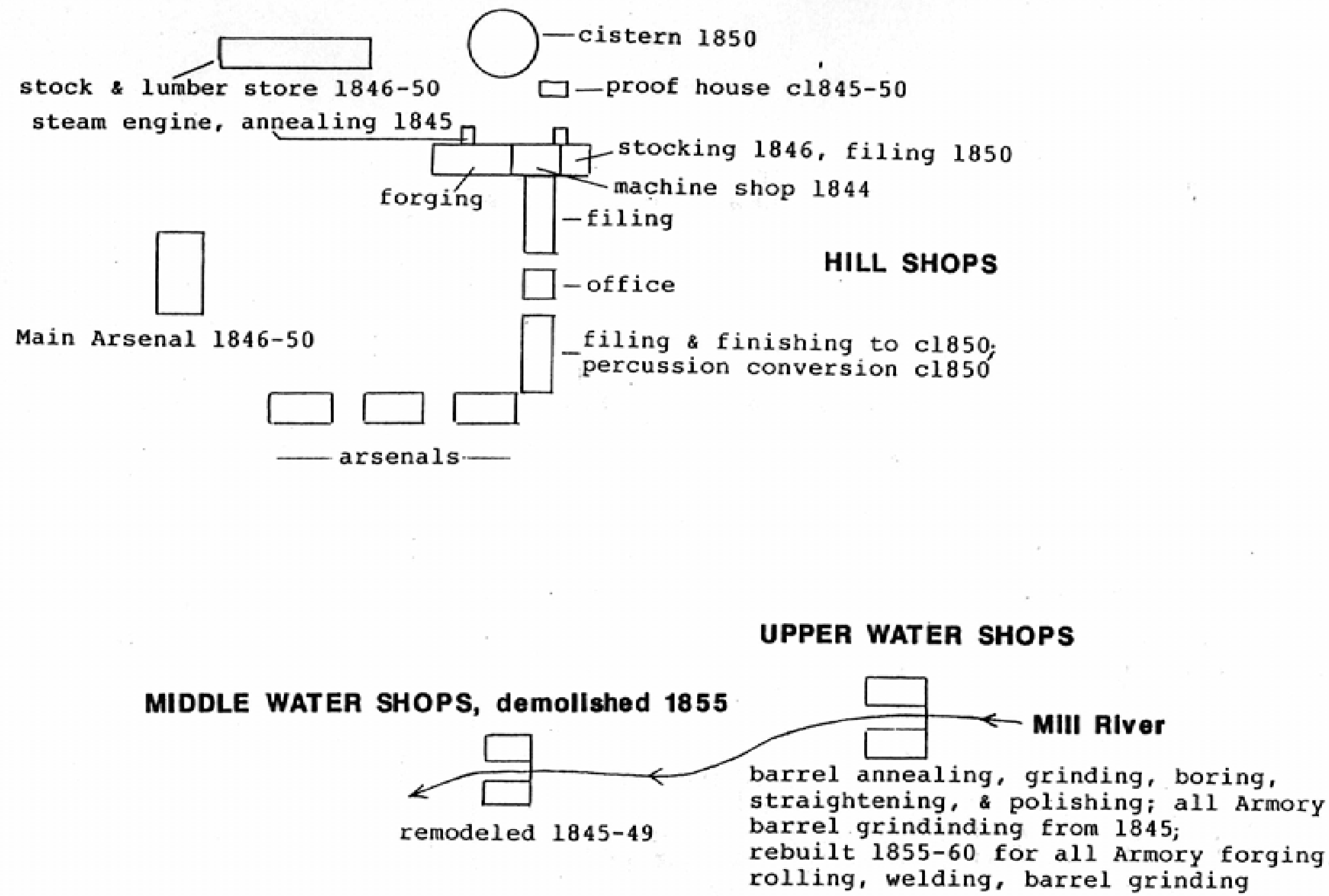


Figure 4.3 SCHEMATIC SKETCH OF SPRINGFIELD ARMORY INDUSTRIAL FACILITIES, c1845-1860
Single dates denote year of construction or start of operation. Not to scale.

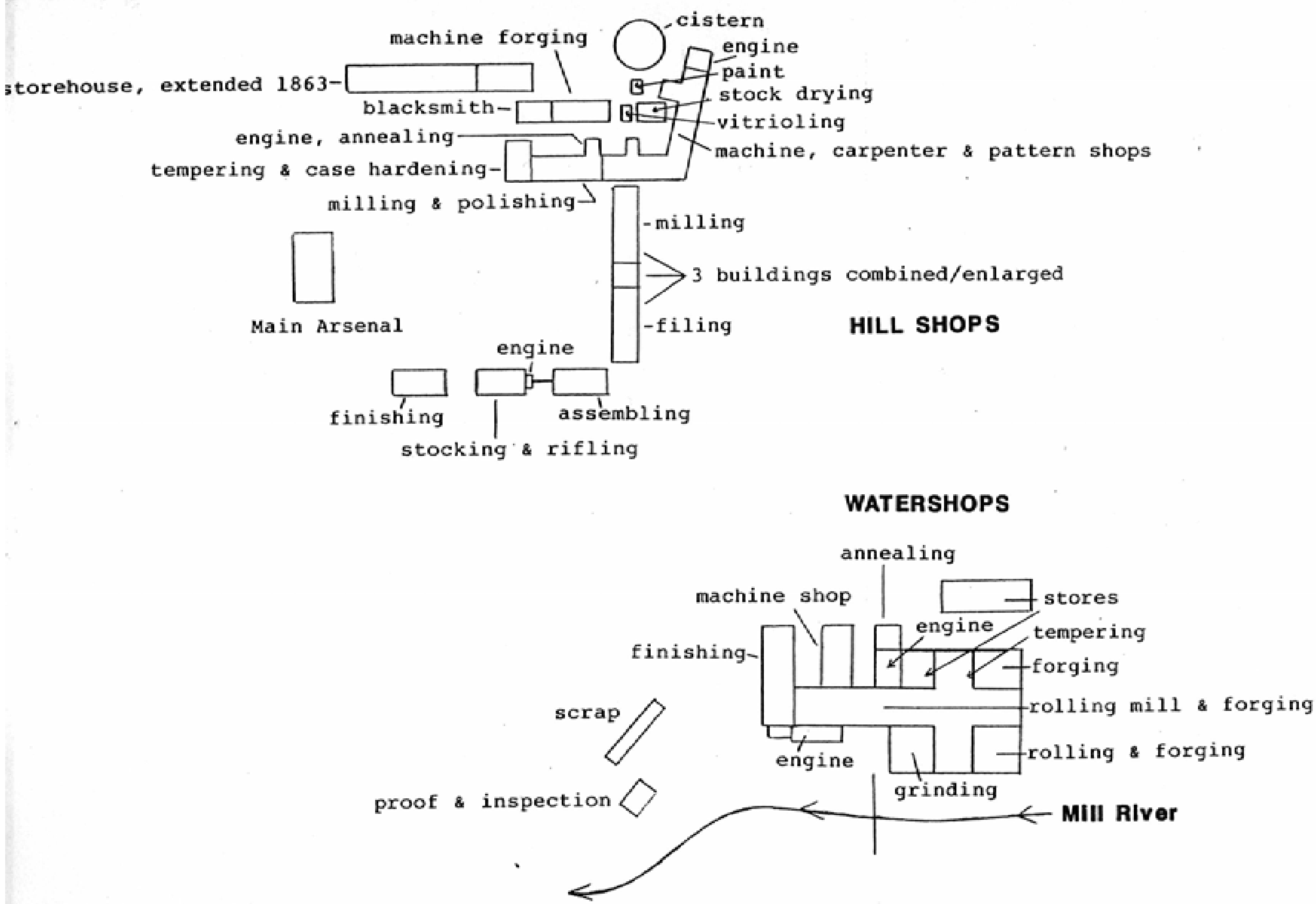


Figure 4.4 SCHEMATIC SKETCH OF SPRINGFIELD ARMORY INDUSTRIAL FACILITIES DURING THE CIVIL WAR, 1861–1865
Not to scale. Sources: Shedd & Edson, Topographical Plan of the Springfield Armory, April 1864;
Plan of Land with the Water Shops belonging to the Springfield Armory, April 1864.

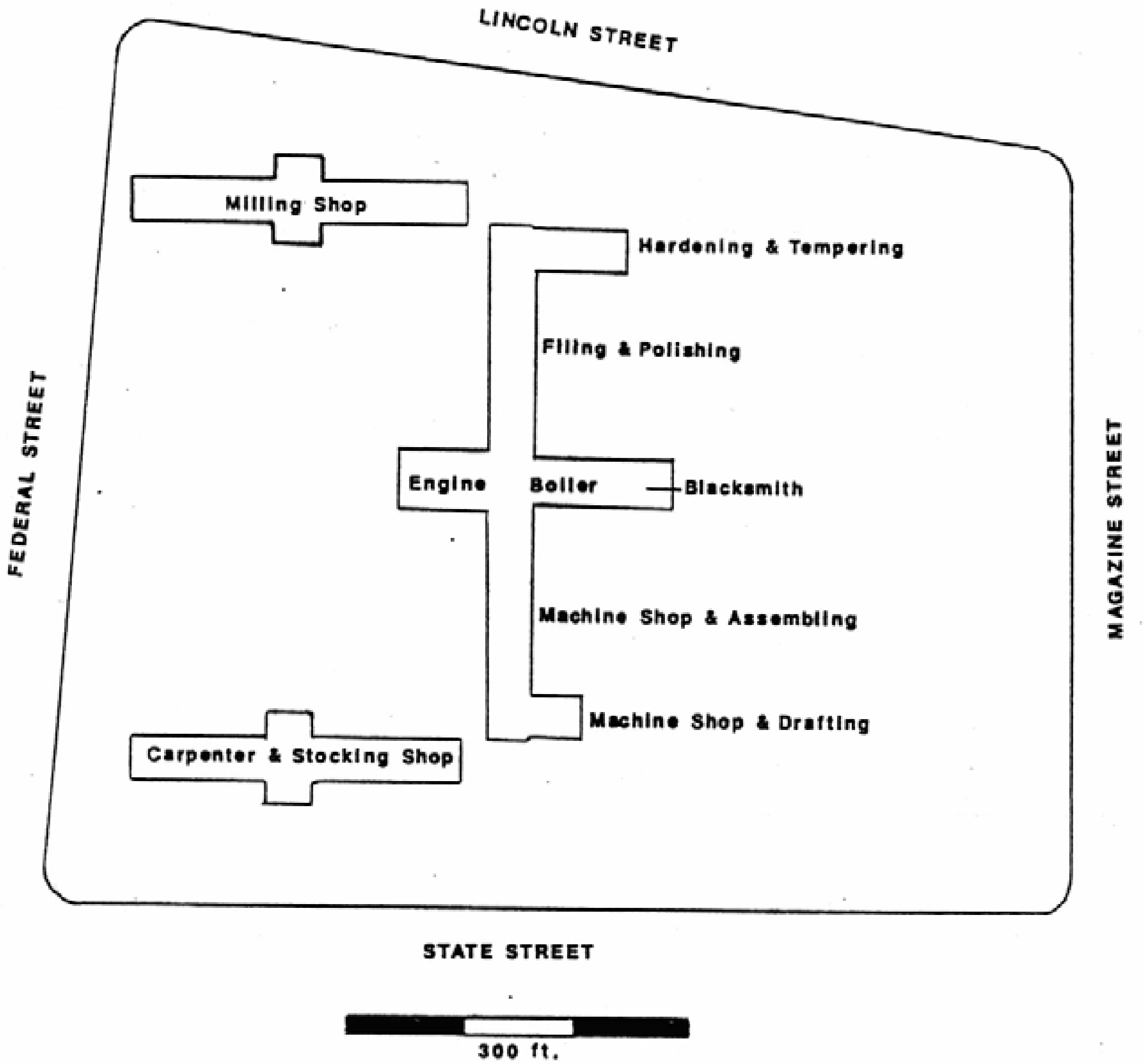
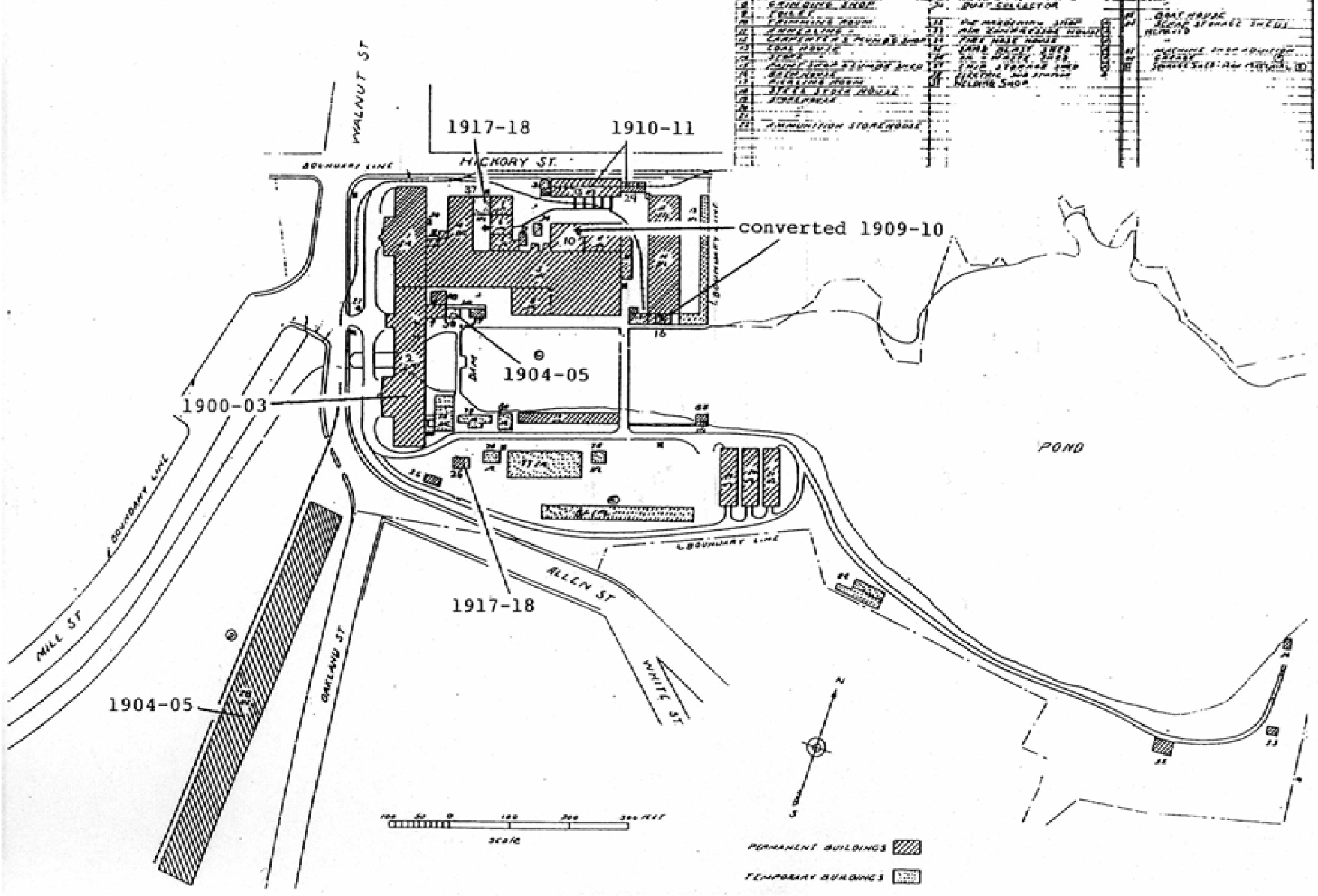


Figure 4.5 FEDERAL SQUARE SHOPS c1888-1894

source: Plan of New Shops on Federal Square, January 1888

Figure 4.6 SPRINGFIELD ARMORY WATERSHOPS, c1900–1918
Dates shown for construction of new facilities.
Base Map: Buildings and Grounds, Water Shops, Springfield Armory, March 1918. SAE 102.



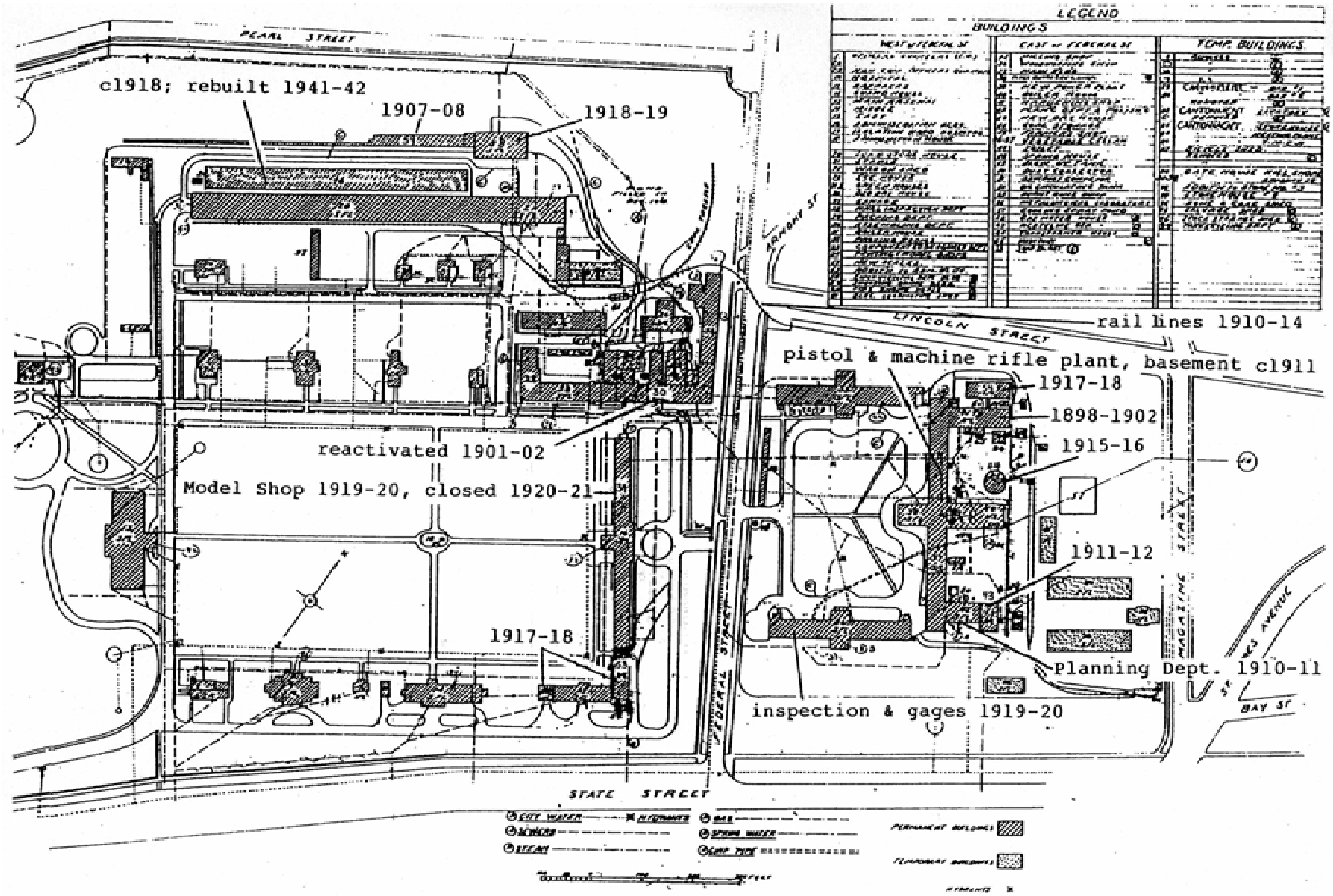


Figure 4.7 SPRINGFIELD ARMORY HILL SHOPS c1895-1918, SHOWING NEW INDUSTRIAL FACILITIES
Base Map Source: Buildings and Grounds, Hill Shops, Springfield Armory, March 1918. SAE 101

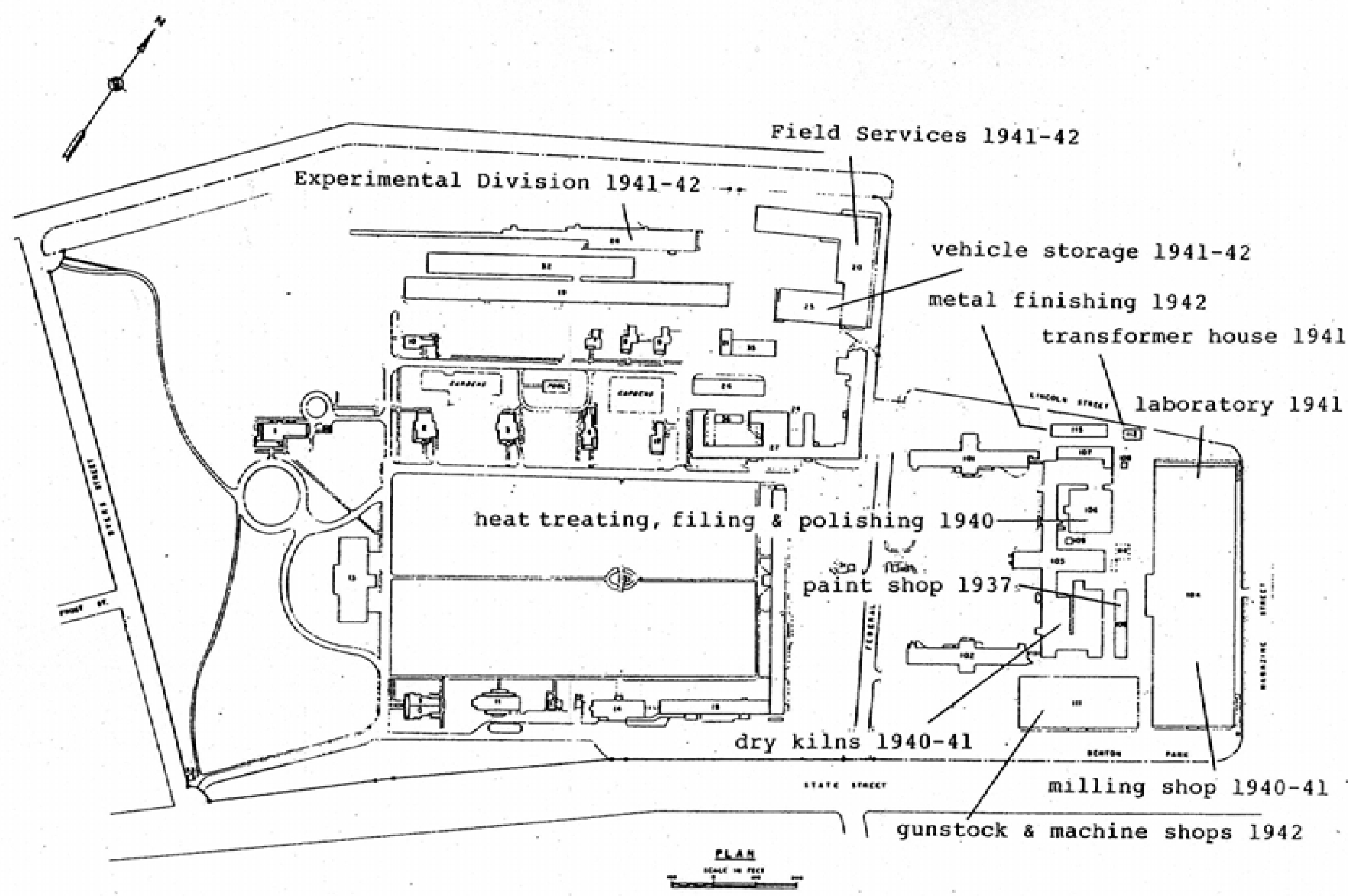


Figure 4.8 SPRINGFIELD ARMORY HILL SHOPS c1935-1968, SHOWING WORLD WAR II ADDITIONS
Base Map Source: Springfield Armory...Landscape Development/Location Plan & Index, 1959. No. 16-12-02

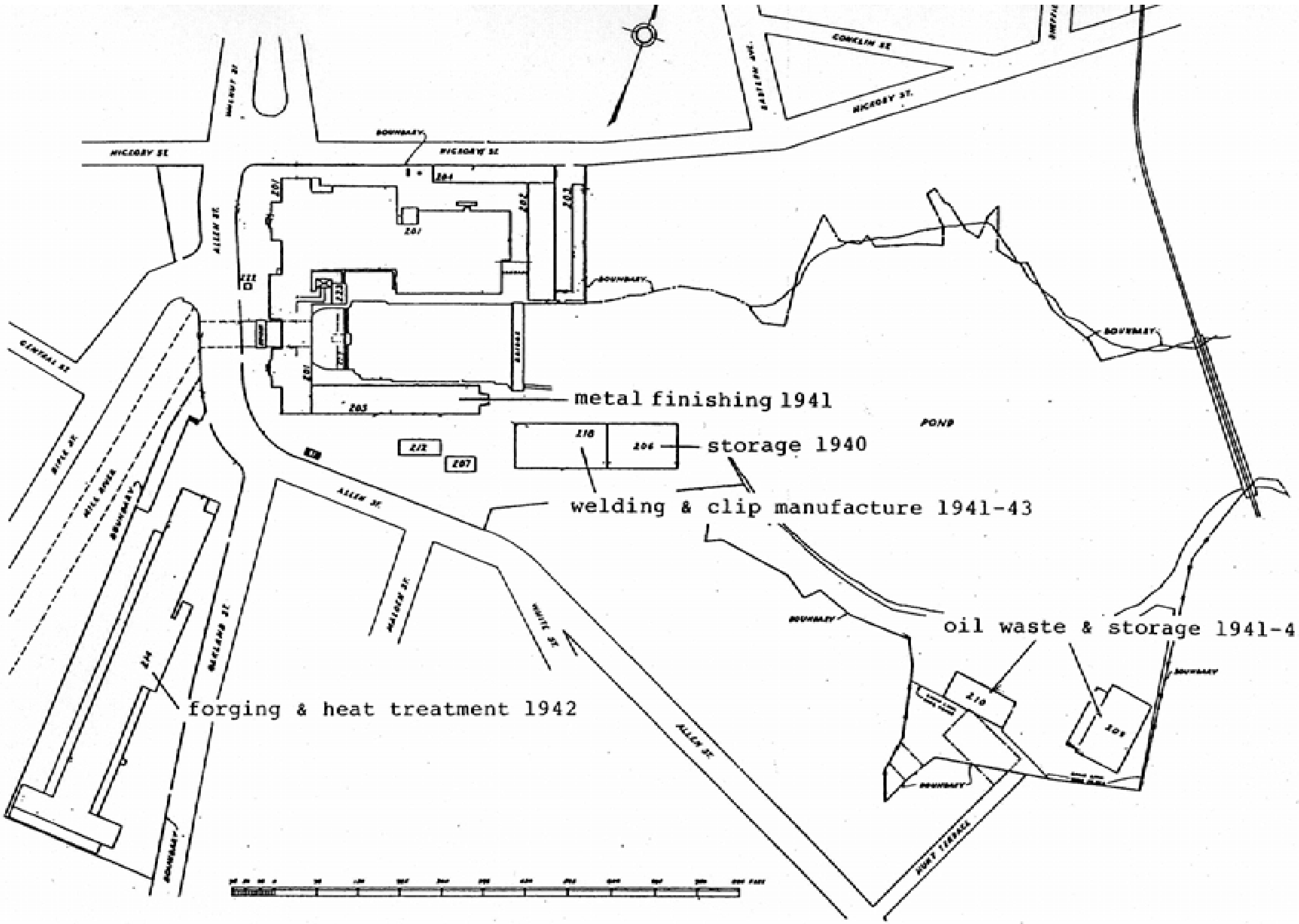


Figure 4.9 SPRINGFIELD ARMORY WATERSHOPS c1940-1968, SHOWING PRINCIPAL WORLD WAR II ADDITIONS
Base Map Source: Plan of Springfield Armory Water Shops showing Telephone System, January 1942

Chapter 5

PROCUREMENT AND MANAGEMENT OF MANUFACTURING MATERIALS

A. Overview of Technical Requirements

Military small arms require superior quality raw materials, acquisition and control of which was a major task for Springfield Armory managers. The metal parts in small arms are subjected to high stresses, wear, and erosion from powder gases and exposure to water. The wood used for the stock must be strong enough to endure the harsh conditions of military service; dimensional stability of the stock was particularly important in flint and percussion arms because the wooden stock held the barrel, lock, and trigger in proper alignment to one another. In addition to materials for small arms, the Armory in its early years had to buy iron castings and forgings for machinery and water wheels, and a variety of specialized materials required in the manufacture of muskets such as grindstones and files. Most of these materials and supplies came to Springfield from distant places. Control of both transport factors and supplier prices in the early 19th century required advance planning to assure that all of the necessary supplies to sustain production of muskets were on hand when needed. Considerable scrap metal resulted from the musket production process and the Armory was involved with development of technology to permit its reuse.

Until 1873 the metal parts of Springfield arms were made primarily of iron. Wrought iron was used because it could be easily forged, welded, and filed.[462] The parts of the musket requiring hardening throughout (springs, ramrod, and bayonet) were made of steel. Walnut stocks and small quantities of brass for the pans completed the list of finished musket material. Iron for barrels was bought in the form of plates, primarily from ironmasters in northwestern Connecticut. Because faults in the iron could cause the barrels to burst upon firing, the quality and uniformity of the barrel iron (or "gun iron", as it was often called) was a special concern of arms makers. The supply of gun iron in the United States was never adequate to meet the demand before about 1860. As the armories put in more machinery, an increasingly uniform starting material was needed to pass through the production process successfully. Because iron makers in the United States could not produce enough

[462] Wrought iron is nearly pure iron containing many fibers of slag that are not eliminated in the refining process used to make it. The presence of the slag particles makes the iron easier to weld.

iron to satisfy this market, dependence on foreign suppliers increased until the time of the Civil War.

After 1873, steel rather than iron was used for most parts of Springfield small arms. The Armory was quite conservative in its choices of materials; it adopted steel for barrels thirty years after commercial armories started using this material. By 1873 the American steel industry was well established and the Springfield Armory, by now a rather minor customer relative to other industries, was able to purchase as much metal as required from steel suppliers. When smokeless powder and bolt action were accepted for military small arms, stress levels in the breech mechanism increased significantly, requiring stronger steel. Again, the Springfield Armory was very conservative in its choice of materials, adopting nickel steel only many years after other armories did. By this time nickel steel was readily available on the open market.

During its first seventy years, the Armory was a major purchaser of the best quality iron available in America and, consequently, was in a position to influence the technological development of the American iron industry. The Armory also bought sufficiently large quantities of other items, such as files, grindstones, and walnut stock blanks, to be a major participant in the markets for these items in the industrial economy of the time. But, in contrast with its important influence on the machine tool industry, the Armory does not seem to have been a significant factor driving technological improvement in the production of the materials and supplies it used. After 1865 the materials needed to make small arms were all common items of industrial commerce; by the early decades of the 20th century they could be purchased under exacting specifications and tested for compliance with these requirements before use. The procurement problems faced by the Armory thus changed markedly as the industrial setting in which it functioned matured.

B. Administrative Procedures for Acquisition and Plant Control of Material

Many of the early production problems at Springfield Armory probably stemmed from defects in materials procurement. Until 1815, a Military Storekeeper and Paymaster at each national armory was directly responsible for all Armory-related purchases, including contract arms, raw materials, rations, construction, and purchased musket components.[463] As outlined in Chapter 2, the paymas-

[463] There is abundant documentation on the extent of early Springfield Armory paymaster responsibilities in Letters Sent by the Military Storekeeper and Paymaster 1799-1853 (RG 156/1389), Contracts for Ordnance, Supplies, and Construction 1806-1918 (RG 156/1382), and Journals of Receipts and Expenditures (R3 156/1380).

ters and the Armory superintendents were in two separate, often conflicting lines of authority within the War Department. It is not presently clear to us how, or even if, these men coordinated the nature, size, and timing of requisitions for arms manufacture. Despite the somewhat secondary position of the superintendent in this period, he had the authority to approve or condemn the quality of delivered material; we do not know if he could specify or request what was ordered.[464]

The reorganization of national armory administration in 1815-16 left the superintendents firmly in charge of acquisition, with the paymasters managing accounts. The Military Storekeeper and Paymaster remained a civilian position at Springfield until 1882, long after the permanent change to military superintendency, probably because Edward Ingersoll filled the office well for the four decades beginning 1842. Ordnance officers thereafter held this job, as subordinates to the Armory commandant.[465]

The superintendent or commandant of the Springfield Armory acted as a factory manager, a role which for materials control involved two major tasks after 1815: acquiring material of acceptable quality and price; and assuring responsible use of material within the plant. As an agent of the government, he or his subordinates contracted for all Armory purchases.[466] Although subject to any federal and military rules governing purchases, he had authority to specify quality or physical characteristics of material, as well as quantity. We have not attempted to reconstruct the complete chronology of such rules, but this authority does not seem to have ever diminished, and during wartime often increased. Advertised solicitations for supply contracts began before 1820 for readily available items such as fuel. For purchases of critical materials with few reliable suppliers, directed negotiations with known suppliers, or what would now be termed "sole-source" contracting, characterized many contracts made until at least the Civil War.[467] The discussion below of iron and steel supplies provides several examples of the latter practice. Iron and steel were the most important and, often, difficult materials to obtain with desired quality. After 1892, metallurgical

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[464] Derwent S. Whittlesey, "History of Springfield Armory," Chapter 4.

[465] Ibid, chapter 7.

[466] e.g., Lee to Boyd, July 16, 1819, RG 156/1351.

[467] Felicia J. Deyrup, Arms Makers of the Connecticut Valley, pp. 68-75.

problems led to increased use at Springfield of physical tests to define and assure steel supply quality. Even with such difficulties, however, advertised solicitations were evidently the rule by the 1890s except in wartime.[468]

Limits to annual appropriations gave Armory managers incentives to control the price as well as the quality of supplies. The Armory was a major American purchaser of iron, stocks, and files in the early 19th century, often giving superintendents the ability to drive down the price of such items with suppliers. Roswell Lee also began the practices of extensive stockpiling and recycling, to control supply prices and assure availability in the event of wartime interruption of commercial networks.[469] Deyrup's research included much effort in documenting prices of different supplies for the period to 1870. We have devoted little attention in this report to the complex issue of Armory production costs or overhead, but it should be remembered that at this federal factory, the price of Armory supplies effected how many arms could be made, but not whether operations would continue. Except in 1877, when there was a substantial delay in Congressional funding of the Armory, annual appropriations assured continued production at some level. Unless questions arose about the propriety of a contract,[470] there was rarely any doubt that supply prices represented the best efforts of Armory managers.

The superintendent or commandant appears, then, to have had great discretion in bringing things to the Armory. There was, from the earliest period of Ordnance Department direction of the national armories, far more department oversight regarding disbursement and accounting of material during manufacture. Once a purchased item became government property, accounts rendered at least monthly to Armory managers tracked its disbursement and use. Quarterly returns to the Ordnance Department summarized this information. Not all the original monthly accounts appear to have survived, and there are no detailed discussions of Ordnance Department accounting system history.[471] Until at least the early 1820s, it appears that Harpers Ferry and Springfield armories used

[468] e.g., advertisement inviting proposals for supplies, June 15, 1892, RG 156/1354.

[469] Deyrup, pp. 68-9.

[470] Whittlesey, chapter 4, reviews some cases of possible conflicts of interest in supply contracting before 1815. Our research has not indicated such problems after the War of 1812.

[471] Merritt R. Smith reviews the types of submittals made by the national armories to the Ordnance Department in "Army Ordnance and the 'American System' of Manufacturing, 1815-1861," pp. 57-8.

different accounting systems for internal handling of materials, but Roswell Lee's far more centralized methods probably became the standard. Rather than allow each worker to take what he needed to make a given arms component, as was the case at Harpers Ferry, Lee organized a nested series of disbursements with written records kept of each step. The Master Armorer provided supplies for each shop to an assistant master armorer or foreman, who in turn disbursed material to each workman.[472] In the absence of data or even hints to the contrary, we infer that this system remained in effect until the early 20th century. Lee's system was based on individual shops as units of management, with the Master Armorer coordinating and overseeing disbursements and accounts.

One problem with the shop-based organization, common to many private firms, was that requests for materials originated with Armory shop managers through the 19th century, and were evidently ordered and stored according to the purpose of the original request. Procurement requests could generate considerable amounts of surplus stock, and were subject to little Armory-wide inventory control.

By the early 20th century, increased Ordnance Department concerns with actual production costs (outlined in Chapter 2) led to new accounting and routing procedures, including factory-wide supply controls with less duplication of orders. Most of these departmental efforts emerged from the application of Frederick Taylor's methods of factory reorganization, beginning in 1909.[473] Springfield Armory generally endured few of these applications, but elaborated on its existing methods of detailed administration and accounting.[474] By 1908, Armory stores were organized by kind, rather than original purchase purpose, and monthly inventories appeared. In the modernization of Armory stores accounting, however, there was apparently direct borrowing from Taylorist methods over the next decade. By 1918, Armory officers could know at any time the nature and quantity of parts and materials on hand, as well as the movements of components between shops during manufacture. A Planning Department, established before World War I, now managed the

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[472] Lee to Bomford, May 12 and December 12, 1821, RG 156/21.

[473] Hugh G.J. Aitken, Scientific Management in Action, esp. pp. 112-14.

[474] ARCO 1913, p. 14.

estimation as well as handling of required Armory material.[475] The Armory thus underwent fairly rapid changes in materials management, most details of which we have not documented here. There were numerous reorganizations of Armory bureaucracy after World War I, but the handling of materials evidently changed little except perhaps in the physical processing of paperwork, with new systems of card filing and early generations of computers.

C. Iron & Steel

The barrel, lock, and mountings of Springfield flintlock and percussion arms were made of wrought iron. Steel was used at first only for the springs, bayonet, and ramrod. As some additional small parts were redesigned during model changes, the proportion of steel to iron increased slightly, from 9% in 1823 to 12% in 1851.[476] Armory artificers used large quantities of steel files throughout the 19th century. Until about the Civil War, the Armory also needed cast and wrought iron for water wheels and for the machinery it built. The establishment of a National armory in 1794 would hardly have been possible had there not been a primary iron industry that could supply these needs already functioning in the United States.

Wrought Iron

Supplies

Iron had been made in small quantities to supply local needs from the earliest days of the American colonies. An iron industry that could operate on an industrial scale began in the Salisbury district of northwestern Connecticut in the mid-18th century. Pig iron made in charcoal-fired blast furnaces was used both for castings (including cannon during the Revolutionary War) and as the raw material for subsequent conversion to wrought iron in establishments called "forges." Some of these forges grew into enterprises of considerable size.[477] By 1765 Samuel Forbes of East Canaan, for example, was selling forge hammers, gun barrels, standardized iron parts for grist mills, and anchors weighing as much as 1000 pounds. By 1780 Forbes & Adam had a rolling and slitting mill that could roll

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[475] ARSA 1908-1918, SANHS.

[476] Springfield Armory, "Estimated Amount & Weight of Stock & Materials Necessary to Make 12,000 Muskets," April 1823, SANHS; Bessey's Springfield Directory for 1851-2, pp. 157-67.

[477] Robert B. Gordon, "Material for Manufacturing: The Response of the Connecticut Iron Industry to Limited Resources and Technological Change."

barrel skelps in place. Forbes & Adam began making wrought iron for Springfield shortly after 1794. Eli Whitney used Salisbury iron for the manufacture of muskets at his armory beginning in 1798, and the difficulty of obtaining adequate supplies of gun iron was one of the reasons he advanced for his failure to meet contractual commitments for delivery of muskets.[478]

Salisbury iron quickly established a reputation as the best iron for arms making; it was shipped to armories as distant as Harpers Ferry.[479] Because of the strong demand, the Salisbury ironmasters were able to charge a premium price for their product, as much as $2 per hundredweight over the price of the best imported iron (about $10 per hundredweight) in 1819, no mean accomplishment for an industry that had long been regarded as backwards and which suffered greatly from foreign competition throughout the 19th century.[480] Roswell Lee attempted to force down the price of Salisbury iron by purchasing iron from Pennsylvania for the Armory, but this material failed to supplant the Salisbury product as the preferred iron for barrels.[481] In 1820 Lee did manage to get a price reduction, but the high cost and unreliable supply of gun iron remained one of his most serious operating problems at Springfield. He journeyed as far as Tennessee in 1824 in search of alternative sources and continued to make trials of other kinds of iron offered to the Armory: none was satisfactory.[482] By the mid-1830s the small arms industry was taking at least a quarter of all the wrought iron made in the Salisbury district and probably all of the best grades made; the Springfield Armory was the largest of these customers.[483]

Iron quality

A new problem with the iron supply arose in the late 1820s. The quality of some of the iron supplied to Springfield from previously reliable sources began to deteriorate so badly in 1829 that Roswell

[478] Jeannette Mirsky and Allan Nivens, The World of Eli Whitney; Kenneth T. Howell and Einar W. Carlson, Men of Iron: Forbes & Adam.

[479] Lee to commissioners of Navy Board, March 8, 1826, RG 156/1351; Charles U. Shepard, A Report on the Geological Survey of Connecticut.

[480] James Dalliba, "Armory at Springfield;" Gordon, "Material for.."

[481] Deyrup, p. 74.

[482] Lee to Springfield Armory, May 6, 1824, RG 156/1362; Lee to Bomford August 1, 1825, RG 156/1351.

[483] Gordon, "Material for Manufacturing.."

Lee sent inspectors to supervise the production in Salisbury.[484] Their efforts were only partially successful. The Salisbury ironmasters were not able to sustain an output of material with uniformly superior properties with the essentially 17th century technology they were using. The problem was exacerbated by the absence of any quantitative way of specifying iron quality. The ultimate test was the failure rate of barrels in proof, but a great deal of labor was invested in a barrel before it was tested; proofing was hardly a satisfactory means of quality control.

At this time the quality of iron was judged by the appearance of its fracture when a bar was notched and broken open. This test depends a great deal on the skill and experience of the inspector and is, in any case, not a sensitive test for so demanding an application as small arms making.[485] Superintendent John Robb reported that six or seven men were furnishing Springfield with iron for barrels in 1833 and that the loss rate was 25% in proof. He had the iron in each barrel marked to show the maker, and then restricted purchases to the best two makers as shown by the failure rates.[486]

Quantitative tests on a large number of iron samples from works in the United States were made at the Franklin Institute between 1832 and 1837 as part of a study of the causes of boiler explosions. The tensile strength of each sample was measured, but the results failed to reveal the extent of the occurrence of bad iron among the different samples submitted: tensile strength is a poor indicator of the quality of wrought iron. Ductility, a good indicator, was not systematically measured in these tests. The importance of ductility in evaluating wrought iron was not recognized until the time of Kirkaldy's researches starting in 1859.[487] Recent study of the 1832 Franklin Institute gun iron test data shows that this iron is stronger and less ductile than bars from other sources that were also tested at this time.[488] Tests made by Richards also show this low ductility, high tensile strength, and

[484] Lee to Holly & Coffing and others, December 3, 1829, RG 156/1351.

[485] Gordon, "Material for Manufacturing.."

[486] U.S., Congress, House, Superintendents of National Armories...

[487] David Kirkaldy, An Experimental Inquiry into the Comparative Tensile Strength..of Wrought Iron and Steel, pp. 95-100.

[488] Robert B. Gordon, "Strength and structure of wrought iron."

low yield strength.[489] Hagner mentions that the Ordnance Manual gives the tensile strength of Salisbury iron as 66,000 pounds per square inch.[490] We now know that the strength properties of wrought iron are sensitive to the design of the test specimen used, and for this reason we cannot be sure that strength mentioned by Hagner is reliable. Nevertheless, the accumulated evidence appears to show that Salisbury iron did tend to have distinctive physical properties.

Because no adequate inspection methods were available, and because pre-1865 American iron-making technology was not adequate for continuous production of superior quality iron on a regular basis, supply remained a serious concern for all American small-arms makers well into the 19th century. As late as 1843, Eli Whitney, Jr., observed that "...it is the most troublesome affair of my business to get suitable Iron for Barrels."[491]

Remington, Whitney and many other private arms makers solved their problem with barrel iron in the late 1840s by changing over to barrels made of cast steel imported from Sheffield, England.[492] However, the Ordnance Department would not allow its contractors to use steel for barrels even as late as 1862, as is shown by the following letter:

June 20, 62

Messrs Sanderson Bros & Co.
New York
Gent:

I have received a letter from Gen Ripley today saying that he will not authorize the reception of Steel barrels for Springfield Muskets but I must follow the materials of model furnished. Under these circumstances it is not prudent to give you an order just now. Could you however furnish me a casting of Iron similar to your decarbonized steel, say an Ingot 2 3/4 in diameter outside, with hole and 10 inches long, weighing 11 or 11 1/4 lbs. These could be cast in an iron mold smoked, with smoked iron core. This ingot I would roll in the barrel machine as usual, but don't call it steel. It must be Iron. It probably would not harden in water, and can properly be

[489] Richards, 1874.

[490] P.V. Hagner, "Proof of musket barrels by hydrostatic pressure at Watertown Arsenal, 1844."

[491] Whitney to Naylor & Co, April 10, 1843, Eli Whitney Papers.

[492] Charles H. Fitch, "Report on the Manufactures of Interchangeable Mechanism," p. 8.

called iron. Let me have your views as to this plan. On this plan by putting in a sett of rolls you could produce splendid barrels of iron, and find great sale for them.
Please consider this letter confidential--You could invoice and import the ingots as cast iron.
If you act in this matter I trust you will do it most promptly and produce samples--The ingot for Navy Musket and Springfield will be slightly different inside, Navy weighs 11 1/4 and Springfield 10 1/4.

Yours truly

E. Whitney[493]

The Springfield Armory did not change to the use of steel until after the Civil War, remaining instead with iron barrels bought from the Salisbury ironmasters. In 1845, for example, Canfield & Robbins reported that they could make about 150 tons of gun iron per year and of this amount, 100 tons was promised to Springfield.[494] Armory iron consumption at this time was about 200 tons per year. To make good the shortfall, the Armory used increasing amounts of imported iron.

Roll welding of barrels

Because of the heavy labor and uncertain results of welding barrels under a trip hammer, Roswell Lee became interested in the possibility of forming the skelp and welding it with rolls. He may have been led to think of this because Armory artificers had experience in the operation of a rolling mill that was erected at the Middle Water Shops sometime between 1810 and 1816 for rolling barrel skelps.[495] He engaged Henry Burden to design and erect a rolling mill in 1828-29 but there is no record that anything came of the plan for welding barrels in these rolls.[496] It does appear, however, that the rolling mill designed by Burden was completed, probably used for scrap by the 1850s.[497]

[493] Eli Whitney Papers, Box 1.

[494] Canfield & Robbins to Ripley, October 28, 1845, RG 156/1365.

[495] Springfield Armory Work Returns, RG 156/1371.

[496] Paul Uselding, "Henry Burden and the question of Anglo-American technological transfer in the nineteenth century."

[497] In surviving Armory inventories, such as "Testimony..on the management..."
p. 150, expenditures for machinery and excavation for the rolling mill are listed for the year 1829 with further expenditures for machinery in 1830 and 1831; a mill, valued at $14,000, by far the most expensive piece of machinery at the Armory listed in the 1834 inventory. This mill remains in the inventories that have survived and is almost certainly the one in use in 1852, when it was described as being used for reworking scrap in Bessey.

Armory managers made another attempt to weld barrels with rolls in 1850, using machinery built by the Ames Company of Chicopee, but by 1851 this effort was abandoned.[498] Later experience suggests that the failure may have been due to the lack of suitable iron rather than a deficiency in the machinery. The British committee that visited Springfield in 1854 described the system of forging barrels by trip hammer then in use as inferior to the rolling mill method used in England. The Ordnance Department received reports on the English method of welding barrels in rolls from Major Hagner in 1848, Major Mordecai in 1856, and from J. T. Ames in 1857.[499] In 1858, Armory superintendent James Whitney retained Ames to acquire an English rolling mill and 50 tons of iron to use with it. By November 1858 the equipment was in operation and Whitney reported that only one of the first hundred barrels made by the new process had failed in proof.[500]

The barrel rolling process depended on use of suitable iron. In 1858, there was only one source of this iron, Marshall's works near Birmingham, England, from which the Armory made repeated orders. When the Civil War began in 1861, Springfield was in the awkward position of being entirely dependent on overseas sources for gun iron as well as steel. Abram Hewitt undertook to make gun iron for Springfield at his Trenton Iron Company, on being guaranteed a price no less than that paid for English iron, and succeeded in making usable iron only after a visit to Birmingham and much technical difficulty.[501] It was not a good investment for the Trenton Iron Company since the market rested on Springfield's determination to continue to use an obsolete material long after the private arms industry had adopted steel barrels.

The experience with iron at Springfield illustrates the technological imbalance that occurred in the antebellum American development of manufacturing. Rapid progress was made in the use of machinery in manufacturing, most strikingly in woodworking but also in metal forming and cutting. There were not corresponding advances in metallurgy. This may be one reason that the application

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[498] ARSA 1850, in RG 156/1354; Deyrup, p. 152.

[499] Stephen V. Benet, ed., A Collection of Annual Reports and Other Important Documents Related to the Ordnance Department, vol. 1; Ames to Whitney, November 3, 1857, RG 156/1365.

[500] Gordon, "Material for Manufacturing..;" Master Armorer Erskin Allin prepared a detailed description of this process for making a barrel, in his papers at SANHS.

[501] Allan Nevins, Abram S. Hewitt.

of power-driven machinery to woodworking was particularly successful: high quality raw material was, and continued to be, available. The iron made in the United States remained inhomogeneous and unsuitable for use in "self-acting" machines or equipment such as the barrel rolls that would only accept material with homogeneous properties. There were even more severe problems with steel.

Steel

Types of steel

Steel is an alloy of iron and carbon; it may contain other ingredients and is then usually called "alloy steel." Before the 20th century, the term "steel" was usually reserved for metal with a sufficiently high carbon content to be hardened by quenching and tempering. Before about 1865 many different kinds of steel made by different processes were in use and the descriptive terminology used in the Armory records is complex. The following definitions will help with the interpretation of these records.[502]

<u>Natural steel</u> is steel made in a bloomery directly from iron ore. It was the earliest form of steel available in the West but was not much used by the late 18th century.

<u>Blister steel</u> is made by prolonged heating of bars of wrought iron sealed in boxes containing coal, a process called "converting." The iron is carburized by this treatment; bars have higher carbon content on the outside than inside and contain the slag inclusions that were present in the wrought iron used for conversion. This steel takes its name from the blisters that form on the outsides of the converted bars due to release of gas within the iron during conversion.

<u>German steel</u> was made from the 17th century onwards in Styria and Carinthia by refining high-manganese pig iron in a finery. It contains alternating bands of high and low carbon content and was considered a superior material for cutlery.

<u>Shear steel</u> is made from bars of blister steel that have been cut up bundled together and welded. It contains bands of different carbon contents and was also commonly called "German steel" even

[502] More detailed definitions appear in K.C. Barraclough, <u>Steelmaking Before Bessemer</u>.

though made in England. If the process of cutting, bundling, and welding were repeated, the product is called "double shear steel."

Crucible steel, also known as cast steel, is made by melting blister steel in a clay crucible and casting into an ingot mold. It is homogeneous and free of slag inclusions, when properly made.

All of the above types of steel were produced in small quantities and were much more expensive than iron. After about 1865, large-scale steel production by the Bessemer and open hearth processes began and the price of steel decreased greatly.[503] The crucible process remained in use throughout the 19th century for production of the better grades of tool steel, however. The "de-carburized steel" used for barrels at the Springfield Armory after 1873 was a steel with a very low carbon content, made by the Bessemer process until 1878 and in the open hearth furnace thereafter.[504]

American steel making

There were repeated American attempts at making steel beginning in 1655, and blister steel made in Salisbury was tried at Springfield in 1799.[505] However, no American maker succeeded in sustained production of steel of the quality needed for production of small arms.[506] American attempts in the 1830s and 1840s to establish the crucible process were also unsuccessful. Because domestic makers were unable to compete with imports in either price or quality, North America remained a principal export market for the Sheffield steel industry during the first two thirds of the 19th century.[507] The use of significant amounts of American-made steel for the manufacture of small arms began with establishment of the tonnage production of steel by the Bessemer and open hearth processes after 1865.

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[503] Jeanne McHugh, Alexander Holley and the Makers of Steel.

[504] Fitch, p. 624.

[505] Barraclough.

[506] Deyrup, p. 80.

[507] Geoffrey Tweedale, Sheffield Steel in America, a Century of Commercial and Technological Interdependence.

Armory steel before 1873

The Military Storekeeper and Paymaster purchased blister and German steel from agents who obtained their supplies abroad from the earliest period of Armory musket manufacture.[508] Armory managers preferred German steel from Germany until 1830, but thereafter ordered most German steel from England.[509] In 1831, for example, the Armory ordered 18,000 pounds of double shear steel and 1200 pounds of "English 4 blister steel" from Sheffield makers.[510] Cast steel was first used at Springfield in 1842 for bayonet blades, ramrods, and springs.[511] In the period between 1848 and 1853, Armory managers changed the main and band springs, tumbler and sear from shear to cast steel, and then found these parts to be more nearly free of seams and cracks.[512] The proportion of cast, relative to blister or shear steel, used at the Armory continued to increase, and by 1850 the well-known Sheffield crucible steel makers Naylor & Co and Jessops were the chief suppliers of steel.[513] In 1852 the Armory purchased 63,000 pounds of cast steel and only 650 pounds of shear steel.[514] Compared to other American industries that needed high quality steel for their products, the Springfield Armory was slow to adopt crucible steel; the nearby Collins Company, for example, used English cast steel for their axe bits from 1826 onwards and were, in fact, one of the largest American customers for Sheffield cast steel.[515]

There were few changes in the amount of steel used in Springfield arms before 1873. The only parts made of steel in the lock of the 1822-pattern musket were the face of the battery and the springs.[516] There were unsuccessful experiments with steel tumblers in 1832; a lock filer broke two steel

[508] Journals of Receipts and Expenditures, 1794-1811, RG 156/1380.

[509] Deyrup, p. 139.

[510] Lee to Jacob Albeit & Co, April 16, 1831, RG 156/1351. The "4" refers to the carbon content of the blister steel, about 1% on the outside and 0.7% inside; we are grateful to Kenneth Barraclough for providing these definitions.

[511] Fitch, p. 617.

[512] Superintendents of National Armories..., p. 167.

[513] Lee to Burton, February 8, 1850, RG 156/1351.

[514] Bessey.

[515] Gordon, 1983a.

[516] Ordnance Department, Ordnance Manual [1850].

tumblers in assembling four locks, and three of the tumblers cracked in hardening.[517] Without artifacts to study, it is impossible to discover the source of difficulty encountered, but Armory managers had more success later. The tumbler, sear, and springs in the lock of the M1842 musket were made of steel, and in 1850 the Armory bought 2,500 pounds of cast steel for tumblers.[518] Steel lock parts in the M1855 rifle-musket are the tumbler, lock swivel, feeding finger, cover catch, sear, and all springs.[519] Recent examination of two broken tumblers from the M1855 model rifle-musket showed them to be made of cast steel, but improperly heat treated, leaving them too hard.[520] Steel parts were introduced into Springfield arms very gradually, and their proper heat treatment was a continuing source of difficulty.

The slow acceptance of steel at Springfield stands in marked contrast to the metallurgical advances being made at the commercial armories. Remington began to use steel barrels in 1846, and was followed by the Whitney Armory and Simeon North in 1848.[521] All Colt revolver parts were English cast stee1.[522] Ordnance Department feeling against steel barrels was such that when Eli Whitney wanted to use steel barrels in contract rifles for the Army in 1862 he was refused permission to do so, as mentioned previously. Experiments with welded steel barrels began at Springfield in 1866, but steel barrels were not adopted until 1873.[523] The first Armory steel barrels were made from a solid bar drilled and rolled into an elongated tube, rather than by welding a skelp. The M1873 rifle was made using 5.8 pounds of iron and 9.5 pounds of steel.[524]

Armory steel after 1873

By 1878 the specifications for the M1873 rifle allowed for either decarbonized steel or iron for parts

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[517] Weatherhead to Lee, March 30, 1832, RG 156/1365.

[518] Ordnance Manual [1850]; Ripley to Fulerton & Raymond, July 3, 1850, RG 156/1351.

[519] U.S., Ordnance Department, Reports of Experiments with Small Arms for the Military Service.

[520] Robert B. Gordon, "Who Turned the Mechanical Ideal into Mechanical Reality?"

[521] Fitch, p. 624.

[522] Joseph G. Rosa, "Sam Colt opted for British steel."

[523] Allin to Benton, September 25, 1866, RG 156/1365.

[524] U.S., Ordnance Department, The Fabrication of Small Arms for the United States Service.

that were not required to be made of steel.[525] By 1884 most steel used at the Armory was obtained from the 12-inch rolling mill at the Midvale Steel Works in Philadelphia, which was regularly producing gun barrel steel and was equipped with open hearth furnaces.[526]

The Krag magazine rifle was made entirely of plain carbon steel which, except for the barrel, was case hardened to produce hard wearing surfaces where required. The barrels were made of plain carbon steel with the following specification:

Element	C	Mn	Si	S	P
Percentage	0.50	0.80-1.00	0.10-0.18	<0.0895	<0.06

Elastic limit, 70-75,000 psi
Tensile strength, 100-120,000 psi
Percentage elongation, 15-20
Percentage reduction, 35-45

The breech end of the barrel was hardened by heating in a gas-fired furnace followed by an oil quenching.

Alloy steel was not accepted by the Armory until many years later. One of the first attempts to get it adopted was made in 1900, when five steelworks submitted samples of barrel steel for testing. The Bethlehem Iron Company supplied a 4% nickel steel which was found to be easily worked and to have good strength properties. It was rejected on the grounds of "fear of seams."[527]

Five types of steel were specified for use in the M1903 bolt action rifle. Quality was monitored by standard tensile tests on samples taken from each lot.[528] The steels specified are all plain carbon steels and cover a range of carbon contents. Until 1917 the most highly stressed parts of the rifle, the receiver and bolt, were made of 0.3% carbon steel which, after machining, was carburized and quenched. This treatment was supposed to give a hard surface on a tough core; actually, the 0.3%

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[525] Ibid.

[526] W.H. Jaques, "The establishment of steel gun factories in the United States."

[527] ARCO 1901, p. 116.

[528] Fred H. Colvin and Ethan A. Viall, United States Rifles and Machine Guns, pp. 9-10.

carbon core was often fully hardened by the heat treatment. Bolts and receivers so made were brittle and failed in service.[529]

The Armory had no metallurgist on staff until c1918, when A.E. Bellis arrived to correct this problem. The carbon content of the steel used was reduced and the heat treatment schedule amended so as to include a reheating to the austenitizing temperature, followed by an oil quench and tempering. The surficial hardness was then tested with a scleroscope. The description of the manufacturing procedure in 1917 does not include hardness test on heat treated parts; the use of the scleroscope in 1918 appears to be the first use of a metallurgical test in Armory production.[530] Hatcher claimed that this double heat treatment produced a bolt and receiver that was stronger than those made of nickel steel by the Rock Island Arsenal, but tests conducted by Crossman showed that while bolts made at Springfield failed by brittle rupture at a load of 21,500 pounds, those made at Rock Island sustained a load of 31,000 pounds and failed with ductile rupture.[531]

It was not until 1927 that the Springfield Armory changed over to the use of nickel steel. Here again, the Armory's cautious approach to alloy steel contrasted markedly with that of a leading private arms maker. The Winchester Repeating Arms Company adopted nickel steel for rifle barrels in 1895, when the change over to smokeless powder took place, and developed the new barrel drilling equipment needed for this material.[532]

The experience with the M1903 bolts and receivers again illustrates the extreme reluctance of the Springfield Armory to adopt modern metallurgical techniques and materials. The heat treatment process that was used for the actions of the Krag and, later, the M1903, was a continuation of the method of hardening musket and rifle parts that had been in use since 1794 -- case hardening. Case hardening was not needed after alloy steel became available for large-scale industrial use. The first alloy steel made in large quantities in the United States was the chromium steel used in the

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[529] Julian S. Hatcher, "Metallurgical improvements in the Springfield rifle."

[530] Cf. Colvin and Viall.

[531] Hatcher; Edward C. Crossman, The Book of the Springfield.

[532] Williamson, Winchester, p. 160.

construction of the Eads Bridge at St Louis in the 1870s.[533] Research on the use of nickel in steel armor plate began by 1889, and after 1894 nickel steel was accepted as the principal general purpose, low alloy steel.[534] Small arms parts such as the bolt and receiver made of nickel steel could be hardened through and tempered to produce the high strength and toughness needed to resist the stresses generated by the smokeless powder, high velocity ammunition adopted for the Krag and M1903 rifles. It appears that until 1927 the Springfield Armory strongly preferred a traditional metallurgical technique -- case hardening carbon steel -- that was inappropriate for the modern-design weapons then being manufactured. After 1927, the Armory used materials, heat-treating procedures, and test methods common to contemporary light metalworking industries.

Metallurgical testing and research

As just discussed, many of the production difficulties encountered at the Springfield Armory were due to metallurgical problems. The most important of these were the uneven quality of the gun iron used for barrels and poor heat treatment (case hardening iron or tempering steel parts). During these same years the Ordnance Department also encountered metallurgical difficulties with the manufacture of cannon. Beginning in 1840 the Department launched a program of testing the properties of iron, examination of broken cannon, and experiments with casting techniques.[535] Tensile tests on samples from the "Peacemaker," the wrought iron cannon that burst on board USS Princeton in 1844, were carried out by Major W. Wade in 1845.[536] Wade designed a mechanical testing machine suitable for experiments on wrought iron and steel, and supervised its construction at the West Point Foundry in 1850.[537]

There is no evidence that the methods or equipment developed by Wade and other Ordnance officers was ever used to test gun iron. In the two volumes of reports on metallurgical experiments

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[533] John A. Kouwenhoven, "The designing of the Eads bridge."

[534] David Dulieu, "A history of alloy steels."

[535] Edward C. Ezell, "The Development of Artillery for the United States Land Service before 1861."

[536] William Wade, "Examination of the iron used in the construction of the wrought iron cannon which burst on board the steamship Princeton, February 28, 1844."

[537] Chester H. Gibbons, Materials Testing Machines.

carried on by Ordnance officers before the Civil War, only two short papers deal with small arms.[538] Both describe the results of testing of musket barrels by hydrostatic pressure that revealed faults in both the welding and the metal used. Wade's 1846 tests were carried out at Springfield using a hydrostatic proof machine purchased that year.[539] There is as yet no evidence that the Armory used this technique. The backward state of metallurgy at Springfield at this time contrasts with the experimentation and development of new methods of preparing iron for cannon by Ordnance officers between 1844 and 1861. Rodman's method of casting cannon in a mold with a cooled core was used by a commercial foundry making cannon for the Ordnance Department, but whether on not the metallurgical testing research had any influence on American industrial metallurgical technology remains to be demonstrated.

In 1899 a "steel board" convened at the Springfield Armory concluded that, "the heat treatment of steel for barrels and receivers at the armory is susceptible of considerable improvement..."[540] The steel board consisted of three officers and Mr. J.E. Howard of the Watertown Arsenal; there was no metallurgist on the Springfield staff at this time. The Armory soon bought a 50,000-pound capacity Riehle testing machine, installed at the Hill Shops, and conducted a series of tests on tensile bars subject to different case hardening treatments. As a result of these efforts, specifications for the steels used were slightly altered and closer temperature control in case hardening was instituted, but there were no basic changes in the materials or procedures used.

By World War I, the conjunction of wartime production demands, the problems with the M1903 bolts and receivers discussed previously, and belated Armory attention to tool steels all demanded a more organized approach to metallurgical testing. The Armory established a metallurgical and testing laboratory in 1917, primarily to test steels purchased for components, tools, and gages. We review the relationship of the laboratory to broader Armory research efforts in Chapter 8. For testing finished components, laboratory personnel gradually turned to hardness testing, an essentially non-

[538] Peter V. Hagner, "Proof of musket barrels by hydrostatic pressure at Watertown Arsenal, 1844," pp. 95-9; Anonymous, Reports of Experiments on the Strength and Other Properties of Metals for Cannon; William Wade, "Experiments made in proving musket barrels by hydrostatic pressure at Springfield Armory."

[539] ARSA 1846, in RG 156/1354.

[540] ARCO 1900, p. 117.

destructive process which could still give general indications of other physical properties such as tensile strength and brittleness. Thus it was ideal for testing finished components such as the critical receivers. The Experimental Department got a Brinnell hardness machine, according to a list of its new equipment in 1920. The metallurgical laboratory added a Rockwell hardness machine, which was singled out as "an excellent metallographic instrument," in 1930.[541]

Armory technicians cut, ground, and polished many specimens for metallurgical analysis, but obviously this process could not be applied to a large number of manufactured components. A metallurgical microscope aided in the inspection of incoming steel and heat treated samples in 1920. By then, tensile, compression, ductility, and impact toughness testing was routine at the Armory. A Charpy impact testing machine is on a 1920 list of laboratory equipment, and the 1900 Riehle machine was probably still in use, although not specifically mentioned. In 1938, the laboratory added a combination cutting and grinding machine for specimens and a new torsion testing machine, among other equipment.[542] By World War II, the Armory had absorbed and adapted most metallurgical testing practices common to commercial light metalworking industry.

D. Wood for Gun Stocks

Black walnut was used for the stocks of all Springfield small arms. This wood is strong and dense and can be accurately shaped with either hand or machine tools. Private arms makers sometimes used other hardwoods, such as maple, for stocks but walnut was always used in military small arms made for the United States government through the period of Armory weapons production. Armory experiments with plastic or other material beginning in World War II did not lead immediately to changes in authorized small arms models.[543]

In the early period of Armory history, walnut stock blanks were obtained from Pennsylvania and

[541] ARSA 1920, p. 16; ARSA 1930, p. 11, both SANHS. The same machine may be in the collections of the Springfield Armory National Historic Site today; a Rockwell machine patented in July, 22, 1930 and supplied by the Wilson Mechanical Instrument Company is presently in storage.

[542] ARSA 1920, p. 14; ARSA 1938, p. 33, both SANHS.

[543] E.g., Springfield Armory, "Springfield Armory Monthly Report of Progress on Research and Development Projects, May 20, 1942 - December 20, 1945," monthly report of May 20, 1942, pp. 23, 30.

Maryland through a military agent in Philadelphia.[544] Quality standards for stocks were stringent: trees from fields were preferred to those from forests, which yielded wood that was more likely to be soft and coarse-grained.[545] Kiln drying was not accepted, and the wood required seasoning for three years before use. The Armory kept on hand sufficient stock blanks for at least several years' production.[546] As discussed in Chapter 4, Armory managers built large storage facilities to handle stock blank inventories, especially between 1846 and 1863. It is clear that a walnut stock blank was a high value item which could bear substantial charges for transportation, handling, and storage. One distinct advantage that the Armory had over private arms makers was the ability to hold a large inventory of walnut without paying interest charges or taxes.

As forest resources near the east coast diminished in the late 1820s, purchased walnut came from farther west. The opening of the Erie Canal in 1825 made it much easier to bring in walnut from western New York and Ohio. Ohio remained an important supplier through the Civil War. In 1865 a typical log was about 2 feet in diameter and 12 feet long, and would yield from 60 to 100 stock blanks, depending on how much defective wood it contained.[547]

E. Recycling

The amount of iron scrap produced in making a musket can be estimated by comparing the amount of iron purchased with the weight of iron in a musket and the number of muskets made. The data needed are available for two years in the early period of the Armory. Of the iron listed in the table prepared in 1823 of materials needed to produce 12,000 muskets per year, only 24% would have emerged in the finished muskets.[548] Data on iron purchases reported by Bessey in 1851 show that the utilization of iron had improved only slightly, to 31%.[549] Much of the waste was in making barrels: in 1848 a musket barrel weighed 10 1/2 pounds when welded but only 4 pounds when

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[544] Deyrup, p.81-3.

[545] Whittlesey, chapter 8.

[546] Deyrup, pp. 81-3.

[547] Chafee to Laidley, September 26, 1865, RG 156/1365.

[548] Deyrup, p. 86.

[549] Bessey.

finished.[550] As late as 1917 a 3 1/2-pound forging was used to make the trigger guard, weighing less than 1/2 pound, of the M1903 rifle.[551] Thus it appears that the manufacturing processes used at Springfield produced considerable scrap well into the 20th century. We expect that any usable scrap would not have been wasted in an institution run by New England Yankees, but we do not have much information about recycling procedures used at Springfield.

One of the early uses made of mineral coal at Springfield was in forges employed in reworking scrap iron.[552] In the 1850s, iron for the smaller parts of muskets was obtained by re-rolling scrap left over from making barrels, and it is likely that this had been the practice at least since the construction of the rolling mill erected at the water shops in the early 1830s.[553] In 1858, the re-rolling of iron scrap was contracted to W. F. Burden at the Troy Nail Works.[554] Superintendent Whitney installed furnaces for reworking scrap and a scrap iron rolling mill at the Armory Water Shops beginning that same year.[555] Scrap storage facilities became increasingly important in later years.

G. Fuel

Because almost all the metal parts of a musket were forged, the Armory required large quantities of fuel for forge fires. In 1823, 8.3 bushels of charcoal were used for each musket made; by 1852 this amount dropped to about 2.0 bushels.[556] Much of this decrease was due to the increased substitution of mineral coal for charcoal. In the earliest days of the Armory, small amounts of bituminous coal (about one part in 15) had been mixed with charcoal in forge fires. When in the late 1820s anthracite from eastern Pennsylvania became generally available, many of the metal working industries of New England began to experiment with it. The Collins Company, for example, realized substantial

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[550] Marco Paul's Adventures in Pursuit of Knowledge, Springfield Armory, p. 76.

[551] Colvin and Viall, p. 155.

[552] Deyrup, p. 86.

[553] Bessey.

[554] Whitney to Burden March 5 and March 9, 1858, RG 156/1351.

[555] ARSA 1858, in RG 156/1354.

[556] Cf. Deyrup, p. 86; Bessey.

savings in fuel costs by replacing charcoal with anthracite in forge fires, with no loss in quality of the axes that they were then beginning to produce in large quantities; after 1829 they used only anthracite for forge work.[557] The Springfield Armory, along with many other gun makers, found that anthracite forge fires were suitable for barrel welding as well as forging, and that fuel costs were reduced by at least a third.[558]

The Armory purchased substantial amounts of charcoal throughout the first two thirds of the 19th century. It was obtained from local vendors who carried on - coaling in the uplands adjacent to Springfield. In September 1822, for example, the Armory received 19,963 bushels of "C coal," 850 bushels of "pine coal," and 110 bushels of "O coal" were received from fifteen vendors.[559] Whittlesey reports that the earliest account books at the Armory show that most of the charcoal purchased was pine coal, with the rest being maple, and that the bituminous coal used came from a small field near Richmond, Virginia, conveniently placed on tidewater.[560] It is not clear why the use of pine coal apparently decreased by 1822.

Larger quantities of mineral coal were needed as the Armory switched to greater use of steam power, at a time when the use of steam in all types of manufacturing in New England was increasing Steam power became economical when the development of canals in eastern Pennsylvania, and of both rail and inland waterways in New England, made it possible to ship coal at low cost. Eventually, the Armory established a rail connection so that direct deliveries of coal could be made, but this was not completed until 1914-15. Shop electrification and oil-fired steam boilers made coal delivery facilities obsolete before World War II.

H. Expendable Tools

In addition to materials and supplies, the Armory made frequent purchases of cutting tools to replace

[557] Collins Company Historical Memoranda 1826-1871, Connecticut Historical Society, Mss 72190.

[558] Deyrup, p. 84. We now know that, at the temperatures used for forging and welding, iron takes up sulfur from mineral coal slowly enough not to be injured. However, mineral coal could not be used in iron smelting without degrading the product because of the higher temperatures used in blast furnace, bloomery, and finery and charcoal iron was demanded by manufacturers for many years after mineral coal was accepted for forge work.

[559] Return of Stock Materials Received, September 1822, RG 156/1381.

[560] Whittlesey, Chapter 8; Journals of Receipts and Expenditures, 1794-1811, RG 156/1380.

those worn out through use. Table 5.1 shows the cutting tools in use in the Armory in 1835. This list is probably representative of the range of tools used through much of the 19th century. Many of the items, such as chisels and gouges, could have been made at the Armory or purchased from the stocks of local vendors. Screw cutting tools were probably made at the Armory until standardized threads became common.

Table 5.1

SPRINGFIELD ARMORY CUTTING TOOLS IN 1835[561]

Wood working (stocker's) tools:	443 Chisels and gouges
	83 Bitts
	19 Saw
Metal working tools:	2404 Files and floats (with 6426 old files in stock)
	425 Drills and countersinks
	324 Taps, dies, and screw plates
	220 Cold chisels
	214 Buff wheels and sticks
	199 Grindstones
	163 Cutters and mills
	95 Augers (for boring barrels)
	30 Hack saws
Other:	15 Circular saws

Files dominate the list of metal cutting tools. A table of materials needed to make 12,000 muskets in 1823 shows that it was expected that one file would be worn out for each musket completed.[562] From the list of purchases for 1852,[563] we infer that file consumption had dropped to about 1/3-file per musket, but in 1862 it was estimated that 6,328 dozen files were needed to make 100,000 muskets, that is, about 3/4-file per musket. The apparent file consumption in 1852 may have been

[561] Inventory of Ordnance and Ordnance Stores on hand at Springfield Armory in charge of the Master Armorer, Dec. 31, 1835, SANHS.

[562] Deyrup, p. 86.

[563] Bessey

low because of files drawn from Armory stocks and not immediately replaced.

Forging to closer tolerances, and the increased use of metal cutting machinery for roughing cuts on forged parts, should have reduced file consumption in the years after 1823, but filing remained an important task at the Armory until well into the 20th century. Consequently, large quantities of files were needed, though they did not dominate Armory purchases so dramatically after the 1870s. Most files were purchased, but some were made at the Armory in its early years. For example, the work return for 1834 shows John Cadon was paid for cutting 200 files and for 2 1/4 days work in "assorting and annealing files."[564]

Until the 1870s, most files used in the United States were imported from Sheffield, England, which dominated the American file trade throughout this period.[565] The English files were sold through American agents. A representative 1831 order for files to Jacob Albeit of Baltimore calls for 1,208 dozen files at an average price of $2.616 per dozen. Half of the files are to be made of cast steel from Ibbotson & Bros. of Sheffield and half to be German steel (which cost 20% less) to the standard of Samuel Wing, also of Sheffield. The list of files to be supplied contains 33 different types; the sizes range from 5 to 13 inches; the cuts include rough, bastard, and smooth; and the shapes are flat, round, 3-square, and half-round.[566] In 1831, the terms "German steel" and "Sheer steel" were used in Sheffield for the same product: forge-welded bundles of blister steel containing alternating bands of high and low carbon content. Perhaps the German steel files were considered more economical to use for some classes of work at the Armory. Samuel Wing was one of the many small steelmakers of Sheffield in the early part of the 19th century.[567] These instructions illustrate the difficulty that early 19th century purchasers of steel and steel products had in specifying accurately the quality of the materials they wanted.

An 1833 order from John Robb to Thomas M. Thompson of Boston called for 917 dozen files, of

[564] Springfield Armory Work Returns, PG 156/1371.

[565] Tweedale 1987.

[566] Lee to Albeit, July 16, 1831 RG 156/1382.

[567] K.C. Barraclough to R.B. Gordon, May 29, 1986 [letter in Gordon's possession].

which 716 dozen were to be cast and the rest German steel by Greaves & Sons of Sheffield.[568] This order was a substantial reduction in the proportion of German steel files from the order of 1831. Since the order required delivery in three days, Thompson must have had the files in stock. The purchase of more than 25,000 files in a period of two years illustrates the large scale use of these tools by the Armory.

Sheffield files were handcrafted. The critical steps were grinding the blank flat on a large wheel by hand and the judgment of the eye, raising uniform teeth with a chisel and hammer blows, and proper hardening. Badly made files usually failed by the teeth being too hard or too soft.[569] There were many American attempts to manufacture files using file cutting machines. Nathan Starr had one in operation in 1849 that he claimed made files as good as the English imports; they were tried at Springfield but none were ordered, apparently because they cost more than the Sheffield product.[570] American makers captured some of the Armory file business during the Civil War, but the Sheffield makers regained their market as soon as the war was over. At that time the Armory had on hand 360,000 files, enough for 20 years of peace-time production.[571] It was not until the 1870s that the Nicholson File Company was finally able to take over the file market in America from the English with machine cut files.[572] It has been claimed that an element in Nicholson's success was the "increment cut" file machine which actually made the teeth of the machine-cut file slightly irregular and so better replicated the hand-made article.[573] We may infer that the increment cut was introduced to cater to the prejudices of filers, and that it did not produce a better product since modern files have teeth with uniform spacing and depth.

[568] Robb to Thompson December 28, 1833, PG 156/1382.

[569] Dionysius Lardener, Manufactures in Metal, Vol. I, Iron and Steel, p.299-301.

[570] Deyrup, p. 142.

[571] Ibid, p. 193.

[572] Tweedale.

[573] Anonymous, "File making by machine."

ABBREVIATIONS IN NOTES

ARCO	U.S., Ordnance Department, Annual Report of the Chief of Ordnance to the Secretary of War for the Fiscal Year Ended June 30, ----.
ARSA	Annual Report of Operations at the Springfield Armory. Titles vary, and reports appear in different archival sources, as noted.
RG 156/	Record Group 156, Records of the Office of the Chief of Ordnance, National Archives. Record entry number follows slash.
SAHS	Springfield Armory Historical Summary for the Period ----, on file at Springfield Armory National Historic Site. These are semi-annual or annual reports covering the years 1951-1965.
SANHS	Springfield Armory National Historic Site. This refers to material held by the National Park Service at Springfield.
SFSA	Statement of Fabrications, Other Work Done..at National Armory, Springfield, Mass. Titles vary. These records, in RG 156/21, appear to be the only available summaries of annual operations c1865-93.

Chapter 6

ORGANIZATION AND SKILLS OF SPRINGFIELD ARMORERS

Perhaps the most remarkable achievement of managers and workers at Springfield Armory was their construction of a flexible production system that had the capacity—unused in normal times--for an astounding expansion of output in times of war and contraction afterward. The most successful demonstrations of this flexibility occurred in response to the Civil War and to World War II. It is inconceivable that the Armory could have achieved such flexibility of output upon those wartime occasions, or have reached even its usual peacetime level of output, by simple growth of its original handicraft production system of the 1790s. Instead, Springfield Armory underwent profound changes characteristic of industrialization. In Chapter 7 we consider the shift from handicraft production to industrial production at Springfield in terms of mechanization. Here we shall discuss this shift with respect to the division and specialization of labor; the payment of wages; the timing, pace and duration of work; the work environment and its permeability; the supervision of work and labor-management relations; and worker skills.

A. Division and Specialization of Labor

If a task such as gun making can physically be done by one person alone, then the rationale for dividing it into two or more specialized operations, to be performed by two or more persons, is that it can be done quicker and--with repeated experience--better. The idea is that a specialist will, by greater opportunity for practice per unit of time, become more adept at a single operation than he will as a non-specialist performing a variety of operations.

Adam Smith, for instance, in 1776 described the now paradigmatic division of pin-making into "...about eighteen distinct operations, which in some manufactories, are all performed by distinct hands, though in others the same man will sometimes perform two or three of them."[574] Gun making in Birmingham, the center of that industry in England, had by the late 18th century also been divided, like pin making, "...into a number of branches...which...are likewise peculiar trades,"[575]

[574] Adam Smith, The Wealth of Nations, p. 4-5.

[575] Ibid, p. 4.

carried on in separate premises. The makers of stocks, barrels, and locks were separate from each other and from the makers of ramrods, bayonets, or of gun "furniture." Separate members of the gun trade had the jobs of boring barrels, rifling barrels, stocking, finishing, polishing, etc. Thus, completion of guns, whether singles or in large lots, "...required extensive shipping of parts and semi-finished guns from place to place within the gun-making districts."[576] This decentralization of gun making operations persisted in Birmingham among sporting gun manufacturers into the latter half of the 19th century, even after the British Ordnance Office adopted the American system for manufacturing military small arms. An account published in 1866 lists 48 different specialties in making and fitting parts together, occupying a total of 7,290 gun workers in Birmingham.[577] A similarly decentralized organization of gun making prevailed in Belgium.[578]

In the American colonies this kind of division of labor did not develop in civilian gun making. Individual gunsmiths of varying degrees of proficiency were able to supplement their own skills by buying imported individual components, such as locks or barrels, from England. Larger scale gunsmiths employed helpers, but it is not thought they divided their labor into specialties on any sustained basis.[579]

At the national and contract small arms manufactories of the new United States, however, the aim was to produce a large quantity of a standard design military musket. Although there was occasional subcontracting for parts among the makers of military muskets, the predominant pattern was to make all parts at the same location, under supervision of the same management. Under these circumstances, there was greater opportunity for rational analysis and reorganization of the total task than there was at Birmingham, where the various specialties had been shaped by the "invisible hand" of market and tradition.[580]

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[576] Russell Fries, "British Response to the American System: The Case of the Small-Arms Industry after 1850," p. 381.

[577] John D. Goodman, "The Birmingham Gun Trade", p. 392-93.

[578] Felicia J. Deyrup, Arms Makers of the Connecticut Valley, p. 34.

[579] Ibid.

[580] A. Smith, p. 423.

Division of labor began early at Springfield Armory, but its precise origins are obscure. The Armory's work records do not provide much detail until several years after 1800. When monthly work returns began in 1806, they already identified at least 22 specific operations plus unspecified day work performed by the approximately 72 armorers.[581] Contract arms maker Simeon North found as early as 1808 that he could save at least a quarter of his labor cost and achieve better quality "...by confining a workman to one particular limb of the pistol until he has made two thousand."[582] After visiting Springfield Armory in 1809, Superintendent James Stubblefield of Harpers Ferry Armory initiated there a "new plan" of "distributing the component parts of the guns so as to make the work more simple and easy." He probably acquired his new plan at Springfield.[583] Yet in the memory of a former master armorer, "...the commencement of the filing by the limb, or the division of labor on the locks, was in 1818."[584] If they were indeed based on component parts or "limbs," these divisions of labor would be of the type traditional in England, although carried on at one location instead of dispersed among separate shops.

However, Dennison Olmsted, the earliest memorialist of contract musket manufacturer Eli Whitney, contrasted the English division of labor by "limbs" of the gun with Whitney's more "philosophical" and untraditional concept of dividing the work according to process rather than product, so that "...several workmen performed different operations on the same limb." As Olmsted described it, "...these parts passed through the hands of several different workmen successively (and in some cases several times returned, at intervals more or less remote to the hands of the same workmen) each performing upon them every time some single and simple operation, by machinery or by hand, until they were completed."[585] In Olmsted's opinion, it was Whitney's system that was subsequently

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[581] "Armorers" may be identified as production workers, as distinct from the superintendent, the clerical staff, the supervisory positions of "master armorer" and "assistant master armorers", and from the workers who maintained the buildings, grounds, and vehicles, all of whom were paid for their time only; see Springfield Armory Work Returns, RG 156/1371, and Payroll Records, RG 156/1379. Cf. Deyrup, who says that in 1806 there were only 58 production workers in "eleven occupations directly concerned with gun manufacture and excluding supervisory work." p. 92, and Appendix D, Table I, p. 240 and Table 4 p. 245. She seems to have ignored not only the production work performed on Armory Hill, for which no work returns survive for this early date, but also the January work return of the "old water shop," where gun parts besides barrels were ground, polished, and filed.

[582] S. N. D. North and Ralph H. North, Simeon North, First Official Pistol Maker of the United States, p. 64.

[583] Merritt Roe Smith, Harpers Ferry Armory and the New Technology, p. 80-81.

[584] Joseph Weatherhead, testifying in 1854, in U.S., Congress, House, Superintendents of National Armories..., p. 91.

[585] Dennison Olmsted, "Memoir of the Life of Eli Whitney", p. 43.

"...introduced into every other considerable establishment for the manufacture of arms, both public and private, in the United States,"[586] but he did not specify when this introduction took place. The Springfield Armory work returns of early 1806 indicate at least some of the work was already being divided according to operation rather than "limb." For instance, butt plates, trigger plates, and barrel bands were being ground by one armorer, and filed by another, while locks were ground by one armorer and polished by another.[587]

From about 72 in 1806, the Armory workforce rose to more than 100 armorers in 1808 and 1809, jumped to more than 200 in 1810 and thereafter remained--with occasional dips into the 100's or spurts into the 300's--at this level for most of the years before the Civil War.[588] During this period, division and subdivision of tasks continued to take place from time to time, as is reflected in the monthly work returns of the Armory. The work returns were reports from each "Shop" or work unit of the Armory as to the number of pieces processed or days worked during that month by each worker. They were paid monthly for day work, piece work, or both, according to the pay rolls that were drawn up from the work returns. In the work returns, some of the shops were named by location (e.g. upper, middle, or lower water shop) and some by function (e.g. "stockers" or "finishers"). Each such work unit was supervised by an "assistant master armorer" (called "assistant principal armorer" in the earlier years and "foreman" later, as discussed below), who signed the work returns before delivering them to the master armorer, who in turn signed them over to the salaried superintendent.

The designations of tasks in these records make it possible to observe the subdivision of labor over the years within an occupation--say, barrel-making or stock-making--as it was broken down into smaller and smaller tasks. Both day work and piece work could be subdivided, but in general, the trend was to convert day work to piece work. Upon occasion, such as tooling up for a new model of gun, or introduction of new machines, piece work might revert to day work for a period while new piece rates were being established. This would also happen if total output dropped sharply, as after a

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[586] Ibid, pp. 43-4.

[587] Springfield Armory Work Returns, January 1806.

[588] Deyrup, Table 4.

war or in a year of low appropriations for the Armory. We shall illustrate the progress of division and specialization of labor in the traditional "limbs" of barrel-making and stock-making at the Armory before the Civil War, but leave aside the making of locks and the other metal parts of the musket.

Making Barrels[589]

As would be expected in a manufactory where work was divided by process rather than the "limb" being worked, the work returns show barrel-making operations scattered over several locations at the Armory: the lower, middle, and upper water shops, and in the shops of the stockers, forgers, and finishers on Armory Hill. By 1820, when about 32 men were working on barrels, the day work as well as the piece work in barrel-making was already divided into a total of 16 tasks specified in the payroll and the work returns. About half of the operations were paid at least partly on a day-work basis: rolling skelps (plates of iron) for the barrels, helping to roll them, four kinds of boring and milling the barrels, filing them, turning them, and breeching them. About half of the operations were paid by the piece only: welding, helping weld, grinding, roughing, polishing, straightening, and sighting. By 1825 no further division of the tasks seems to have occurred, but they had all been put on a piece-work basis.

This arrangement continued until 1835, when "1st boring" by the piece and "2nd boring" by the day were added to the list (to augment "boring" "counter boring" and "finish boring"), as was "milling barrel squares" by the piece. In 1840 "studding" barrels and "drilling tangs and barrel vents" were added to the operations in barrel-making, now performed by a slightly larger work force of 36. In 1843, following a period of many changes at the Armory, the barrel-making work force dropped to about 25 men, but the number of specified operations still rose to include "3rd boring," "curve barrel plates" and helping to curve them, tapping barrels, and separate operations of milling the barrel butt and milling the barrel breech. All of these operations were paid by the piece.

By 1850 the barrel-making work force had grown bigger and the specified operations more

[589] This section reports analysis of January work returns for 1820, 1825, 1830, 1835, 1840, and 1843 (the last year for which work returns are available), and of payrolls for January in 1820, 1850, and 1856, and for May in 1859. Since this sample is for only nine out of 480 months in the period covered (i.e., less than 2%), and fluctuations did occur between months and between years, quantitative statements should be understood as approximate, not absolute.

numerous than ever before, to around 47 men who performed about 27 operations. These included "jigging" the barrels, filing barrel butts and barrel breeches, "1st" through "4th" milling, "1st" through "5th" boring, and cleaning them. Six years later, however, barrel-making shrank to around 13 men performing about ten undifferentiated operations, such as plain "boring," "welding," and "polishing" the barrels. That year, 1856, was a year of exceptionally low output-2,721 small arms--at the Armory. By the end of 1859 output had rebounded to 13,002; in May of that year, out of a payroll of 233 armorers, there were 29 men performing 31 operations in barrel-making, including six boring operations besides counter boring, five ("lst"-"3rd" and "6th" -"7th") milling operations, and two jiggings. Thus, compared to the performance of 16 barrel making operations by 32 men in 1820, the number of men had remained about the same, but the work was about twice as finely divided.

Although some of the armorers worked at one barrel operation all month long--for example Harvey Mills, who cone-seated 1275 barrels in May, 1859--others did several operations each, including non-barrel work. For instance, Orlando Chapin in the same month 5th-bored 1,178 barrels and studded 146 barrels, and also 2nd-filed 447 butt plates. In addition to these piece-rate operations, he also worked briefly on tools at a daily rate of $1.90.

Making Stocks[590]

Over the same span of time, the division and specialization of labor in stock-making began later than in barrel making and progressed proportionally further, from one overall operation designated simply as "stocking guns" in 1820 to about eighteen operations by the time of the Civil War.

The piece rates paid to stockers in 1809 ranged from $.65 to $.80 per gun stocked.[591] These rates rose in the subsequent years, which included the inflationary War of 1812. In early 1820, several months before Thomas Blanchard's newly-invented irregular turning lathe was adopted at the Armory, around 34 men were employed "stocking guns" at piece rates of $1.06 to $1.16 per gun. Using hand tools, a stocker was capable of stocking about two muskets every three days. By June

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[590] For a more extended discussion of the shift from hand to machine stocking, see Carolyn C. Cooper, "A Whole Battalion of Stockers."

[591] Lt. Col. John Whiting, Report #2 on Springfield Armory, 1809, reprinted in James E. Hicks, United States Ordnance, Vol. II, p. 132.

the Armory had enough machine-shaped stocks to supply some of the stockers, who began stocking "with turned stocks," at a ten-cent lower piece rate than those who continued to work "with rough stocks."[592]

Machine operations for stocking disappeared from Armory work returns and payrolls during the period, from mid-1823 to the end of 1827, of Thomas Blanchard's inside contract at the Armory. Blanchard developed a series of special-purpose machines for different stocking operations, and paid the operators of these machines out of his contract price of 37 cents or 32 cents per stock. Thus, for this period the stocking operations designated in the Armory work returns misleadingly rose from only two ("stocking with turned stocks" and "stocking with rough stocks") to only three, summarizing the additional operations as "Half-stock'd with Machine" by Thomas Blanchard.[593] But after Blanchard's production line of 14 machines for "half-stocking" was in operation at the lower water shop he personally left the Armory, whereupon the work returns distinguished seven machine-related operations of six to seven men in that shop, in addition to the hand tool work of about 21 men who were stocking only "half-stock'd" guns at 50 cents each on Armory Hill.[594]

This arrangement for stocking by undifferentiated hand-tool work and specified machine-related operations persisted for a decade until 1840, a year of major reorganization at the Armory, when the hand-tool work was also divided into seven operations.[595] At the same time, machine work on the

[592] Springfield Armory Work Returns for stockers, January and June, 1820. The turning of the stocks presumably took place at the lower water shop, which was the location of later stocking machine operations, but this work was not so designated until mid-1822 to mid-1823 work returns, when the machine operations "turning stocks", "letting in barrels" and "letting in locks" were recorded occasionally as performed by individuals who were previously reported simply as "working" in the lower water shop. Work returns of the lower water shop 1822-23.

[593] As mentioned in Chapter 7, Blanchard's "half" of the stocking comprised shaping the exterior of the stock and fitting on the barrel, lock, butt plate, and barrel bands, plus boring major screw holes, while the "other half"--the remaining hand-tool work--comprised fitting in the trigger and its guard, the ramrod in its groove and closed channel, and the band springs, plus smoothing (sanding) and oiling the stock.

[594] In addition to "turning stocks," the stocking machine operators at the lower water shop in 1830 were grooving for barrels, fitting in barrels, cutting in locks, fitting on locks, boring for and fitting on butt plates, and fitting on sets of bands. January 1830 work returns for stockers and for lower water shop.

[595] The seven hand-tool operations were "sandpapering stocks," "shaping stocks," "grooving, boring, and letting in rod springs," fitting in band springs," "shaping between bands, "putting together" and "fitting edges" of stocks. Work Return for stockers, January 1841.

stocks was further subdivided into 13 operations.[596] These new operations seem to reflect the addition

of two new machines for inletting the trigger guards and bedding for ramrods, hitherto hand-tool operations, and also greater specialization in preparing the exterior of the stock. In all, about 14 hand stockers and 8 machine operators were performing about 20 stocking operations.

By the end of 1843, the last year for which work returns are available, three more stocking machine operations had been specified: "finish turning stocks," "cutting in rod springs" and "grooving for rod." The hand-tool work of the stockers was adjusted accordingly, to differentiate "shaping butts [after] first turning" from "shaping butts [after] second turning" and to specify "fitting rod stop and spring."[597] The number of stockers had declined to about seven hand-tool workers and six machine operators. In early 1843 the work returns began reporting (to two decimal places!) the number of hours each armorer worked that month at each operation, as well as the number of pieces he had operated on and the piece rate he was earning. From these data for December we have calculated that on average the total process of gun stocking, performed in about 21 operations by 13 machine operators and hand workers, was taking over three and one-half man-hours per stock produced, and the various piece rates for hand and machine work totaled 60.2 cents per stock.[598] This constitutes a very large increase in productivity over the mode of stocking before 1820, which had taken about 1 1/2 man-days per stock.

In 1845-46 the stock-making machines were moved from the Lower Water Shop to Armory Hill, so machine and hand operations for stock-making were for the first time located together, and were no longer separated in work returns. By 1850 about 15 men were performing fewer--about 17--operations than in 1843. Three had been newly specified since then,[599] while several had been

[596] The six newly specified ones were "cutting in guards," "boaring [sic] for [rod] stoppers," "gauging and cutting tangs to stocks," "spotting and sawing stocks", "grooving and milling stocks" and "planing and facing stocks." Work Return for lower water shop, January 1841.

[597] December 1843 Work Returns for stockers and lower water shop.

[598] Work returns for December 1843 of the lower water shop stocking operations show 1 hour 9 minutes per stock, costing 19.9 cents per stock, while those of the stockers on the Hill show 2 hours 25 minutes costing 40.3 cents per stock.

[599] The newly mentioned operations were "boring for side and tang screws," "spotting" in conjunction with shaping butts and completing stocks, and "rough turning". Springfield Armory Payroll, January 1850.

dropped from mention. Approximately the same division of labor remained in effect when English Parliamentary Commissioners visited in July 1853 and particularly admired the stock-making production line.[600] The following summer another group of English Commissioners visited and timed the gun stocking operations. They totaled one-and-a-half man-hours per gun.[601] The decrease of two hours per gun since 1843 indicates a great increase in efficiency of the gun stocking process in the interim. Curing that decade the original Blanchard machines had been largely replaced by Cyrus Buckland's new, more complete production line of machines (see Chapter 7). Presumably because of this increased efficiency, in the same ten years the labor cost of stocking dropped from 60 to 42 cents per gun.[602]

In mid-1859 slightly fewer (13) men were performing about the same operations as in 1853, except that "boring for rods" and "fitting band springs" were now specified. More stockers, seven, were engaged in "shaping and completing stocks" than in any other operation. It was a broad, residual hand-tool operation, earning the highest piece rate (22 cents each), and was usually the only task of those who did it. William C. Amidon, for instance, shaped and completed 208 stocks in May 1859, to earn $45.76. Other stockers, however, performed several operations each during the month, such as William Bradbury, who spotted stocks, grooved for barrels, fitted in barrels, fitted on bands, and riveted on tips, for more than 1,000 muskets each operation, and also did a day's work on shop fixtures, to earn a total of $53.21.[603]

The production system at Springfield Armory was severely challenged by the need for much greater output in the Civil War, but in the stocking "limb" it met that need with roughly the same degree of division and specialization of labor that it had reached in the 1850s. The payroll for January 1864 shows about 180 men performing 19 stocking operations--virtually the same 17 as in 1853 and 1859, plus the previously unspecified operations of "first turning tip of stock" and "fitting on tips." More than half, 109 of the 180, were engaged in the hand-tool work of "completing stocks," while

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[600] July 1853 Payroll. Nathan Rosenberg, ed., The American System of Manufactures, pp. 364-66.

[601] Ibid. p. 137-42.

[602] Ibid. p. 146.

[603] Springfield Armory Payroll, May 1859.

the next greatest number, only nine, were assembling rifle-muskets. Compared to the division of labor in early 1820, the number of stockers had increased more than fivefold (from 34 to 180) but the labor was about 19 times more finely divided (from one specified operation to 19).

Divisions of Labor after the Civil War

Although the Armory enrollment and output shrank drastically after the Civil War, the division of labor for stock-making remained remarkably stable. In January 1878 the same operations were listed as in January 1864 plus three due to model change in the meantime (boring for tip screws and side screws and cutting for receivers) bringing the number to about 22, performed by only approximately 13 hand and machine stockers.[604]

Twenty years later, however, the number of operations had gone up to about 27, performed by about 30 stockers. Only six stocking operations in 1898 were traditional ones concerned with shaping the stock and bedding trigger guard, barrel, and buttplate into it. The new operations since 1878 were mainly due to a major change in the stock, since the Krag rifle came with bayonet grips, hand guards, and oilers, requiring turning, boring, grooving, rabbiting [sic], and chambering.[605] Compared to the division of labor in mid-1859, the number of stockers had more than doubled, (from 13 to 30) but the number of operations had increased by only a little more than half (from 17 to 27).

Meanwhile, barrel making had also undergone further division of labor since before the Civil War. The number of operations had increased by nearly half from 31 in mid-1859 to 45 in early 1898, while the number of workers performing them almost tripled from about 29 to about 82.[606] The subdivisions did not affect all operations equally. Thus, for instance, rolling of the barrels remained one of the operations that had not been subdivided, while three turnings and five straightenings were now differentiated in the payroll. (Rolling in 1898, however, was performed to elongate a drilled bar of "mild" steel rather than to weld a tube formed from a wrought iron plate as in 1859. So the same

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[604] Springfield Armory Payroll, January 1878.

[605] Springfield Armory Payroll, January 1898.

[606] Springfield Armory Payrolls, May 1859, January 1898.

single term "rolling" conceals a technological change in operation.)

Perspectives on Division of Labor at the Armory

Was the similarity between the degree of subdivision in stock-making and barrel making (around 150% in both cases) over the period of nearly 40 years since 1859 just coincidental, or did it reflect a more fundamental process? To address this question would require considerably more research and analysis of the changes in both these two activities, and in the other "limbs" of the manufacturing process (the firing mechanism and the mountings), than falls within the scope of the present exercise. A few generalizations are possible, however, from the analyses of the division and specialization of labor in making barrels and stocks between 1806 and 1898.

We may first note that although the trend was for finer subdivision, it was not irreversible: upon occasion previously subdivided tasks were lumped together again, as was particularly noticeable in barrel making in 1856. Second, it is clear that although some individual workers specialized for long periods in only one operation on one part of the gun, others performed several operations in somewhat different combinations in different months. Third, the divisions had more than one cause: some, both in hand-tool and machine operations, reflect changes in the machinery being used; others reflect changes in the model gun being produced; others seem to have resulted from increases in the scale of output. A final possible cause was the classic presumed desire by managers to save on wages by differentiating pay for lengthy operations and those requiring higher skill levels, from pay for shorter operations and those requiring less skill. (The setting of wages and piece rates, intimately bound up with division and specialization of labor, is discussed later in this chapter.) Finally, we should emphasize that the division and specialization of labor made for a flexible production system that was available in times of need and collapsible when unneeded.

In all cases the subdivisions did not just happen, but were the result of conscious analysis and rationalization of the work process at the Armory by the "visible hand" of managers.[607] How did these changes affect the armorers whose labor was divided? Did their subdivided and specialized jobs become "deskilled" and degraded? Early in the century, even those managers who approved of the division of labor at the Armory felt that it was detrimental to the career of any individual

[607] Alfred Chandler, The Visible Hand: The Managerial Revolution in American Business, p. 1.

armorer in terms of "learning a trade." Major Dalliba in 1819 expressed the opinion that:

> The general arrangement of the workmen to their work is the best that can be adopted for the United States, but not so for the interest of the workmen....each workman becomes an adept at his part. He works with greater facility, and <u>does the work much better</u> than one could who worked at all the parts. This is undoubtedly the best method for Government. The consequence, however, to the workmen is, that not one of them becomes a finished armorer. If he is always employed at the Government factories, it is no matter for him; he is, in fact, the better for it, for he does more work, and gets more money; but if he wishes to set up business for himself, he has got no trade; he cannot make a fire-arm.[608]

Similarly, Superintendent Roswell Lee, who was himself vigorous in dividing the labor at Springfield, warned the father of a potential employee in 1825 that "...there are but very few in the Armory that work at all branches...and although it might afford him a living yet it would not be a trade that he could set up and carry on, for himself under ordinary circumstances... [as could a] carpenter and joiner, Cabinet maker, or black or white smith...."[609]

Major Dalliba and Colonel Lee perceived at close hand one of the effects of industrialization: the old trade of gunsmith as they knew it was breaking up. They saw that a young man would not be able to learn all-around gunsmithing skills at the Armory. But they were perhaps too early and too close to the changes to perceive the benefits. As we discuss later in this chapter, making interchangeable small arms parts required considerable hand and eye skills, skills highlighted by the division of labor and not readily replaced by machine work. The new division of labor according to process rather than product also gave Springfield armorers experience that they could use in transferring to factories producing objects other than small arms. Other traditional trades such as textiles or papermaking were also undergoing industrialization, creating a demand for machine builders and operators, as would the new modes of transportation by steam. During the 19th century machine tools developed for use in arms and textile manufactories in turn encouraged the development of new products such as sewing machines, typewriters and eventually bicycles and

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[608] Major James Dalliba, November 5, 1819, in <u>American State Papers V: Military Affairs</u> Vol. II, p. 543, emphasis in the original.

[609] Lee to Riddell, February 13, 1825, RG 156/1351.

automobiles. For all these other purposes the skills the armorers were learning at Springfield became applicable (even as the term "armorer" became antiquated). A geographically mobile expert forger or machinist or welder or even filer could apply his skills at any of several diverse manufacturing establishments, and was not, as Dalliba and Lee expected, doomed to remain a deskilled "armorer" at the Armory.

Economic historian Nathan Rosenberg has pointed out the importance of machine tool development to "technological convergence," in which "industries which were apparently unrelated from the point of view of the nature and uses of the final product became very closely related (technologically convergent) on a technological basis—for example firearms, sewing machines, and bicycles."[610] The same point applies to the human skills used in those industries as to the machine tools. As is discussed below, rewards to the skills of workers in the small arms industry usually stayed above the wages for the comparable skills in other industries. This constitutes evidence for the technological convergence of the armorers' skills and the skills needed in those other industries. The managers of the Springfield Armory and the Ordnance Department recognized that those skills were indeed in demand elsewhere. They needed to retain skilled workers at the Armory; accordingly, they paid a higher wage.

B. Wages and Piece Rates

Lists or "tariffs" of wage rates for both day work and piece work at Springfield Armory were recommended by the superintendent and promulgated by the Ordnance Department. Wage rates were intended to be as high as the highest rates for equivalent work in the Springfield vicinity. They sometimes slipped, usually upward, but sometimes downward, from that standard. Table 6.1 compares the mean monthly wages of the Springfield Armory production workers with the mean monthly wages of some other small arms workers and machinists in Connecticut and Massachusetts, in some years between 1810 and 1870.

[610] Nathan Rosenberg, "Technological change in the Machine Tool Industry, 1840-1910," p. 16.

Table 6.1.

AVERAGE MONTHLY WAGES AT SPRINGFIELD ARMORY AND COMPARABLE PLACES IN CONNECTICUT AND MASSACHUSETTS, 1810-1870[611]

Year	Spring-field Armory	Mass. Private Arms-Makers	Mass. Other Machine shops	Mass. State Average	Conn. Private Arms-makers	Conn. Other Machine shops	Conn. State Average
1810	$22.07						
1822	30.49				$23.58		
					25.00		
					27.78		
					41.67		
1832	33.17		$39.00-52.00		39.00		
			$39.00-52.00		39.00		
			$39.00-52.00		39.00		
			$39.00-52.00		39.00		
			$39.00-52.00				
1845	34.13	$32.50-45.50					
1850	37.84	38.00		($29.21)	30.00	$21.66	($40.44)
		33.50			52.00		
					46.66		
					30.00		
1860	49.01	45.00		(42.50)	34.00	33.33	(37.50)
		46.66	33.33		50.00		
					44.44		
					41.64		
					40.00		
1870	70.53	76.64		(69.77)	65.66		(57.29)
					86.59		
					58.96		
					32.00		
					33.75		

[611] Deyrup, Appendix D, Table 7, p. 249 and Table 3, p. 241-43. Except where parenthetically noted, each wage or wage-range represents one firm.

The workers were paid monthly, at daily rates, piece rates, or both. They were also debited for any work that they spoiled. In the first two decades of the Armory, wages were paid partly in kind: in addition to money, each armorer received a ration and a half per day in the form of flour, pork, beans, soap, candles, vinegar, salt, and whiskey. But after 1814 the equivalent value of these provisions, worth 14.5 to 20 cents daily in 1805, was added to the money wages.[612] By contemporary standards, the early armorers received relatively high pay. Some rough figures are available for low, medium, and high-paying jobs: In 1802, the lowest-paying jobs yielded about $87 a year. These jobs were polishing, filing, helping, working by the day, and tending shop. Moderate pay--about $168 per year--went to those whose jobs were helping to draw skelps or weld barrels, grinding barrels and other parts, stocking, and some forging and special polishing jobs. The highest-paying jobs other than foreman earned about $331 per year: cutting and drawing skelps, welding barrels, breeching barrels, and finishing muskets. By 1815 the annual pay for these three job levels had risen to about $207, $408, and $416, respectively.[613]

Payment on a piece-rate basis began very early at the Springfield Armory. An Ordnance inspector in 1809 reported "most of the work is done by the piece."[614] By 1819, 192 of the 244 workmen at the Armory were reported to "work by the piece."[615] It long remained the mode of pay that was preferred by the workers who received it and the managers who paid it. The Ordnance Department report in 1819 extolled piecework:

> The plan of having the work done by the piece is, undoubtedly, the best of all possible plans....It gives this advantage, that every man is paid according to his merit; it excites ambition and industry, and brings into operation and usefulness the otherwise dormant powers of the mind. It has a moral, good tendency upon the workmen, and at the same, or a

[612] Deyrup, p. 107.

[613] Constance M. Green, "The History of Springfield Armory," Vol. I, pp. 18-19.

[614] Whiting to Eustis, Jan. 13, 1810, reprinted in Major James E. Hicks, United States Ordnance, Vol. II, p. 129.

[615] Dalliba, p. 542. Cf. Table II for January 1820. Probably Dalliba was counting workers who were paid even partially by the piece, for 192 is close to Deyrup's tally of 194 for those paid only by the piece, plus those paid by "both systems."

> far less price, gives annually to the Government a much greater number of arms...[616]

A former long-term worker at Springfield who testified before a Congressional committee in 1854 had a more balanced but generally favorable assessment:

> Day-work and piece-work have each their peculiar advantages and disadvantages to the workman...[Piece-work under the civilian superintendents] allowed the expert workman the benefit of his dexterity; there was therefore considerable variation in the number of hours per day spent in labor on different pieces, some working more hours than the day-workmen, and some less....The piece-workmen, I think, performed more work for the money they received than the day-workmen...I never knew of any dissatisfaction. Same day-workmen wanted to work by the piece.[617]

On the same occasion, former master armorer Joseph Weatherhead said "Hands, as a general thing, prefer to work by the piece to working by the day."[618]

Table 6.2 indicates a growth in the proportion of production workers paid at least partly by piece rates, from just under one-third in 1810 to over four-fifths in 1820, after which it generally stayed high. Although piece rates were used at such private arms factories as those in New Haven and Pittsfield, they were said to be much less prevalent there than at the Armory.[619]

The superintendent or commandant of the Armory usually established tariffs of rates, with the approval of the Ordnance Department; occasionally, special boards appointed in Washington to investigate and determine the wage structure recommended new tariffs. As the division of labor progressed, so that the work became more finely divided, piece rates in some instances were calculated to 4 decimal places, which suggest close attention to the time taken by the work performed on each piece. We have found no direct evidence of exactly how rates were determined prior to the 1830s, and methods of timing could be relatively casual, as discussed in the following pages. Based on testimony given in 1854, however, we can infer from much earlier statements that

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[616] Ibid, pp. 542-3.

[617] Joseph C. Foster, in <u>Superintendents of National Armories...</u>, pp. 55-56.

[618] Ibid, p. 93.

[619] John Robb, in ibid, p. 15.; Foster, ibid., p. 55.

the piece rate or "price" was always based on dividing "a fair day's work"[620] by the number of expected pieces of a given component a diligent armorer could be expected to complete in a fair day.

Table 6.2.

PIECE WORKERS AT SPRINGFIELD ARMORY 1810-1870[621]

year	(a) Production workers, total no.	(b) Workers by piece only	(c) Workers by day & piece	(d) Piece-workers, % of total
1810	204	55	11	32
1815	203	56	6	31
1820	236	134	60	82
1825	247	161	40	81
1830	250	160	49	84
1835	229	153	36	83
1842	226	137	46	81
1845	213	126	36	76
1850	334	229	43	81
1855	135	69	44	84
1865	1,298	1,235	281	66
1870	571	272	129	70

Use of a day's work to calculate piece rates began early. Chief of Ordnance Decius Wadsworth wrote in 1812 that Springfield armorers were paid about $1.40 a day (compared to about $.40 paid their counterparts in France and England) and that piece rates were determined on that basis. He noted that the productivity of U.S. armorers was about 1 1/4 times higher than that of the French,

[620] Captain William Maynadier, ibid., p. 64 and passim.

[621] Source: Deyrup, Tables 2 and 4 of Appendix D, pp. 242, 245. The numbers of production workers paid only by the piece (column [b]) and those paid by day and piece (column [c]) are from the January work returns; total numbers of production workers (column [a]) are from the January pay-rolls. The percentages of production workers who were piece-workers at least some of the time (column [d]) were derived by dividing the total number of production workers into the sum of those paid solely and partly by the piece [d=(b+c)/a]. Deyrup's tables generally lack definitions of categories such as production workers, and we have found that some of her numerical conclusions do not withstand close inspection of Armory accounting records. However, her tables are reasonable outlines of trends at Springfield.

which did not, however, completely make up for their higher wages.[622] The same daily wage figured in Superintendent Roswell Lee's calculations several years later, when it was reported that he had settled the piece rates for the various operations, such that "good industrious men" would be able to earn $1.40 per day.[623]

Yet behind the notion of a set fair daily wage was recognition that the value of the particular amount named might go up or down in terms of what it could buy, so that the nominal daily wage might need adjusting. One would like to know about changes in "real" wages rather than nominal wages, but it is very difficult to determine real wages for this period.[624] All we can say is that nominal wages were adjusted in both directions because of changes in the cost of living. They were also of course subject to counteracting pressures on the superintendent both to save on the costs of production and to retain his best workers. Under directions from Wadsworth to retrench, Lee laid off forty men in 1817-18, and limited most skilled workers to $40 a month. When asked to adjust the prices to the deflation the currency was experiencing in 1820, he reduced wages about 8% that April, and 16 months later further reduced day laborer wages 12% and piece rates 15%. However, to meet competition for workers from the growing cotton textile industry, Lee managed to get permission to raise wages again by January 1825, after many principal workmen said they might leave the Armory. Meanwhile, although Lee frowned upon the practice, job opportunities or "chances" at the Armory were privately sold by the workmen (for about $100) which suggests employment there was deemed desirable.[625]

When an appointed wage board attempted to revise the tariff downward in 1832, protests by the Springfield workers, carried over the heads of Lee and the Ordnance Board to the Secretary of War, brought about reconsideration and they obtained a small increase in wages instead. The board appointed in 1832 grouped Armory occupations into six classes by the degree of skill and intell-

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[622] Wadsworth to the Secretary of War, January 27, 1812, RG 156/5.

[623] Dalliba, p. 542.

[624] For discussion of this difficulty, see "Real-wage trends: 1800-1960," in Stanley Lebergott, <u>Manpower in Economic Growth: The American Record since 1800</u>, pp. 137-153, and William N. Parker and Franklee Whartenby, "The Growth of Output before 1840," pp. 191-216. Deyrup has nevertheless derived a real wage index for armory workers 1802-1861, which she shows in her Appendix D, Table 3, p. 241-43, and Figure 1, p. 244.

[625] Derwent S. Whittlesey, "A History of the Springfield Armory," Chapter 5.

igence required for the jobs; then for each class they decided on a standard wage for a man of average skill and energy working a ten-hour day. Within the six classes they made recommendations as to piece rates and the number of pieces to be expected of such a man in a good day's work, on the basis of information from management and workmen. They also compared the Armory's wages with those in machine shops making textile and other machinery. The board expected their wage schedule would allow the Armory to obtain and keep superior workers, yet lower the labor cost for muskets almost down to its 1821 level. After the workers' protest was carried to Washington, the Secretary of War sent Brig. Gen. John Wool to redo the board's calculations in 1833, resulting, as mentioned, in a slight raise of wages.[626]

Lee's successor in 1833 as superintendent, after a few months of temporary service by Lt. Col. George Talcott of the Ordnance Department, was another civilian, John Robb, during whose 7 1/2-year tenure nominal wages rose, for instance by 10-12% in 1836 alone.[627] When asked later how the tariff of prices was arrived at, he too said it "...was regulated for piece-work according to the amount a man could do in a day." The example he mentioned for the daily wage rate had gone up from the $1.40 of the Wadsworth-Lee era: "For instance, one man might make twenty pieces of a musket and would earn $2 per day and another would make enough to make his pay $1.75 per day, and so on according to their classification."[628] This is the earliest statement we have found of how piece-rates were calculated, although it also suggests that Robb was not overly concerned with whether the daily wage held to a predetermined figure. He denied having increased prices for piece work without authorization from the Ordnance Department, but said that he had "equalized" them: "where one man made certain parts of a musket and received more for doing it than another man who did equally as much work as the other...I would in that case equalize the pay of both."[629] He did not explain how he measured equal amounts of work on different pieces of the musket.

Maj. James W. Ripley succeeded Robb as superintendent in 1841. Later testimony provides a clearer description of his procedure for determining what rate per piece would yield "the price of a

[626] Deyrup. p. 165, 169, 172.

[627] Ibid, p. 165.

[628] Robb, in Superintendents of National Armories...., p. 15.

[629] Ibid, pp. 16-17.

fair day's work" by "a man with ordinary industry":

> ...he took some of the most trustworthy workmen he could find, and requested them to work for a certain time, say a month or more, on piecework by the day. In that way he ascertained very accurately how many pieces entering into the composition of an arm constituted a fair day's work. Then, in conjunction and consultation with the master-armorer and foremen, he determined what rate of wages each man's skill and service entitled him to, always giving him the highest rate of wages paid at private establishments in the vicinity for like services and the same degree of skill....For instance, if a workman's skill and services were worth $2.50 per day, and that was the highest amount the neighboring private establishments were paying, and an ordinary day's work was twenty-five pieces, the price of ten cents per piece was looked upon as the right tariff or rate per piece.[630]

In this statement we can see that the rate an individual workman would earn for a given operation depended not only on a measurement of output by "trustworthy workmen" during an experimental period, but also on some recognition of the "service" of an individual workman as well as his "skill," and of the wage rates prevailing for such a worker in the vicinity.

Major Ripley was acting to carry out the recommendations of a commission appointed in 1841 which had studied work at the Collinsville ax factory in Connecticut and at private armories in New Haven and Middletown, Connecticut, and in Millbury and Pittsfield, Massachusetts, plus several large foundries in New York City. The commission had concluded that wages at Springfield Armory were nearly half again higher than those for comparable work in those places. They recommended a reduction to rates that would be higher, but not that much higher, than those in the private establishments.[631] These new recommended rates added up to a labor cost of $6.50 per musket, which was lower than the $8.27 reported as the actual labor cost in 1841,[632] and is about half the total production cost of a musket as estimated by the Ordnance Department at that time.[633]

[630] Maynadier in ibid., p. 65.

[631] Charles Davies, John Chase and Daniel Tyler, "Report of the Board convened at Springfield, Massachusetts August 30, 1841 to examine into the condition and management of Springfield Armory;" Deyrup, p. 166.

[632] Joseph Weatherhead in "Testimony..on..the management of the national armories," p.86.

[633] Deyrup, Table 1, Appendix B, p. 230 gives $12.78 per musket as the estimated production cost for 1842 and 1843, $13.00 for 1846 through 1855.

Col. George Talcott of the Ordnance Department argued in mid-1842 that the Armory's wages were indeed better than those of private manufacturers, to judge by the number of applications--about 40 a week--for an Armory job.[634] Besides the new wage rates, 1842 was a year of adjustment at the Armory in many other ways, to production of the new percussion model musket and to the new military superintendent. The entire plant was shut down from August to November for repairs, during which time much of the workforce was laid off. Thomas Warner, who as master armorer had overseen the retooling of the Armory for the new musket, resigned in December 1842 to become foreman at the Whitney Armory in New Haven.

During Ripley's thirteen-year "military" superintendence, the nominal wages at the Armory drifted upward somewhat from the level established in 1842, until March 1854 when it was reported that the average daily wage was $1.63.[635] By 1852, the total cost of a musket was reportedly down to $8.75, yet workers were paid at rates that enabled them to earn more per day than in 1841, because of the "...introduction of new and improved modes of manufacture, better machines, a superior degree of order, system, and economy in every department, and other similar causes."[636] According to one of the commissioners who studied the Armory in 1854 and testified about it in Congressional hearings, the wages had risen by 25 to 50 percent in the previous decade, so that many workers who had formerly received $1 a day now received $2 or more. However, he added, productivity had also increased, and "The increase...in the amount of work turned out more pays the increase in labor."[637] This opinion is roughly confirmed by Springfield Armory records, which have suggested an increase of 69% in output per worker over the decade 1844-54 (see Table 6.3). Table 6.3 also shows, however, that productivity had been higher in many of the years earlier than 1844; its fluctuations make a trend on the basis of any two years rather misleading. Many factors, including introductions of new models and production methods, influenced Armory productivity.

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[634] Whittlesey, Chapter 5.

[635] Jefferson Davis, Secretary of War, deposition in Superintendents of National Armories..., p. 140. This agrees rather well with the average monthly wage of $45.28 for January 1854, shown in Table I, but only if one assumes the average number of days worked in a month was nearly 28.

[636] Jacob Abbott, "The Armory at Springfield," p. 161.

[637] John Steele, governor of New Hampshire, in Superintendents..., p. 40.

Table 6.3
LABOR PRODUCTIVTIY AT SPRINGFIELD ARMORY 1804-1870[638]

Year	Production workers, number	Long arms produced, number	Output of long arms per worker
1804	76	3,566	46.9
1810	204	10,302	50.5
1814	225	9,585	42.6
1820	236	13,200	55.9
1824	244	14,000	57.4
1830	250	16,500	66.0
1834	251	14,000	55.8
1840	238	5,967	25.1
1844	165	7,656	46.4
1850	334	20,171	60.4
1854	166	13,000	78.3
1860	182	9,601	52.8
1864	2,467	276,200	111.9
1870	571	46,229	81.0

In the following decade, nominal wages increased greatly during the Civil War, rising 15-20% from December 1863 to July 1864, with a revision of the rate tariff every three months.[639] By October 1863, the armory was employing 2600 workmen and was running "day and night."[640] The annual output per production worker in 1864, the peak year, was apparently more than 100 muskets, carbines or rifles, dropping somewhat after the post-war contraction (Table 6.3).

From time to time over the decades 1840-1900 the idea arose to change the basis of pay at the Armory from piece work and day work to an hourly wage, but this did not take place. Chiefs of

[638] Deyrup, Appendix B, Table 2, p. 233 gives numbers of muskets, rifles, and carbines produced at Springfield Armory each year from 1795 to 1870; her Appendix D, Table 4, p. 245 gives the number of production workers on the payroll at the beginning of each year from 1802 to 1870. As noted for our Table 6.2, however, questions about Deyrup's definitions and counts of production workers require some caution in a too literal use of these figures.

[639] Whittlesey, Chapter 5.

[640] George B. Prescott, "The United States Armory," p. 436.

ordnance George Talcott and George Ramsay recommended this change to the Secretaries of War in 1842 and 1864, respectively, and Chief of Ordnance Alexander B. Dyer, who had served as superintendent at the Armory during much of the Civil War, suggested it in 1865 as a way of achieving uniformity of wage policy between the Navy and Army.[641] When, by decree in July 1868, the hours of work at Federal installations were limited to eight per day, the fact that wages for some workers were based on days (and quarter days) worked, and for others on the numbers of pieces operated on per month, led initially to confused responses at different arsenals. Some commanders began paying 1 1/4 days' wages for a continued 10-hour day; others paid for the 8-hour day what they had formerly paid for the 10-hour day; still others, including Springfield Armory, cut back wages along with the hours, but allowed two hours overtime.[642] The Ordnance Department ordered in February 1869 that the practice should be to reduce the hours to eight but pay the same former daily wage. At Springfield this was a windfall for the day workers, and the piece workers simply worked "harder during eight hours to receive the same compensation" as before. The tacit assumption apparently persisting at the Armory was reported thusly in 1883: "...piecework is so arranged that only a certain total per day of wages is the workman permitted to make."[643]

During the major reorganization of labor that accompanied the retooling of the Armory for the Krag rifle in the 1890s, new classifications of jobs, grades of skill, and wage rates were established. The piece rates were still based on a daily wage and it was still implicit that a maximum output should not be exceeded, since no more than the daily wage set for a given job at a given degree of skill would be paid. For instance, a board of foremen and an officer met in 1895 to plan the organization of work in the milling shop for producing 80 arms a day, to go up to 100 in six months. The superintendent, Colonel Mordecai, told the board from what daily wages at what grades they should calculate the number of pieces to be considered a day's work for a medium worker of each grade. For profiling there were three grades, to range from $2 to $2.50 per day; for milling there were seven grades, to range from $1 to $2.50 per day, and so on. The maximum daily wage for the top grade of all the jobs in the milling shop was $2.50.[644]

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[641] Dyer to Wise, February 15, 1865, RG 156/5.

[642] Dyer to Belknap, December 22, 1871, RG 156/5.

[643] Benet to the Secretary of War, April 17, 1883, RG 156/5; also Benton to Treadwell, February 15, 1869, RG 156/21.

[644] ARSA 1895, in ARCO 1895, pp. 66-7.

As in the Civil War, the scale of operations at Springfield Armory again expanded and contracted dramatically during and after the briefer Spanish-American War. The manufacturing work force tripled from 594 to 1,839 in a few months between February 8 and June 30, 1898; they were deployed in day and night shifts.[645] After the war, production was scaled back and about 1,000 workmen were discharged in 1900, which offered an opportunity to retain "the most efficient men" as graded by a board of foremen and assistant officers, and to fill later vacancies by rehiring the best of those dismissed.[646]

At the turn of the twentieth century, the Armory began a new system for guiding such decisions on wages, promotions, and reductions in the labor force. An efficiency record card began to be kept for each worker. As much of the Armory's work had been put on a piece rate as was considered possible, with rates originally set to let a man's daily wage equal the value of his daily work to the government. Then, if increased output was considered to be due to capital improvement, rather than to the man's increased labor and skill, a new piece rate was adjusted downward just enough to give him the same old wage per day. But if, on the other hand, greater output was considered to be a product of greater labor and skill independent of the machinery, the rate was adjusted upward to increase the worker's daily wage, but only by half of what the increase would have been at the old piece rate. In a mixed case of increased output due to improvement in skill and in equipment, a proportion of increased wages was given "to each party in the adjustment."[647] The grounds for making these difficult judgments and the means of determining the appropriate proportion in the mixed case were unspecified.

Once having made this distinction, however, between productivity gains due to labor and to capital, the Armory management seems not to have followed through with any immediate rigor in lowering wage rates when productivity rose for either reason. Annual reports in subsequent years, during production of the model 1903 rifle, occasionally remarked with apparent self-congratulations when

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[645] ARSA 1895, in ARCO 1895, p. 88.

[646] ARSA 1900, in ARCO 1900, p. 99.

[647] Ibid.

improvements from fixtures, tools, and gages or from reorganizing the work (that is, not from increased skill or job experience) reduced the production cost per rifle, without any reduction in wages, or even with a wage increase. Such reductions in cost per rifle were reported as an unspecified amount in 1903, $.50 in 1909, $.61 in 1910, and $.21 in 1912.[648]

The 1910 saving of $.61 per rifle was accomplished even though "...258 out of a total of 934 employees, or more than 27 per cent, have had their day rating increased" and that output among piece workers went up, "...resulting in a material increase in their day's wage," even with an unchanged piece rate tariff. Reportedly this increase in piece workers' output resulted from their having "...now given up the idea formerly somewhat generally held that...some certain limited number of components constituted a day's work."[649] The 1910 changes also included the shift to a piece-work basis of work formerly made at daily rates, including assembling operations and barrel rolling, "operations to which it [piece work] was formerly considered inapplicable."[650]

Despite the statements made in 1910, the long-standing implicit ceiling on the daily wage for piece workers, and therefore something of a ceiling on their daily output, by no means disappeared. This ceiling may have been a mutual understanding between Armory management and labor, rather than an official policy. A new work routing system introduced in 1912, which reduced the working hours needed to make a rifle from 24 to 17, led to continued increase of output and lowered costs, with no change in the piece rate tariffs except for those operations in which "in consequence the increased work done by the workmen has resulted in an actual increase in the amount earned."[651] This presumably refers--for the first time in Ordnance Department or Armory reports—to piece rate cuts of the kind outlined in 1900 when the system of efficiency-record cards was inaugurated.

Although the Springfield Armory did not undergo any study of its production methods by outside efficiency experts during the heyday of Taylorism, its managers were aware of efficiency studies

[648] ARCO 1903, p. 44; ARCO 1909, p. 49; ARCO 1910, p. 617; ARSA 1912, p. 8, SANHS.

[649] ARCO 1910, p. 617.

[650] Ibid; ARSA 1910, p. 10, SANHS.

[651] ARCO 1912, p. 44; ARSA 1913, p. 2, SANHS.

elsewhere, such as the one at Watertown Arsenal which provoked a strike there in 1911.[652] They became more self-conscious in the years preceding World War I about such subjects as cost accounting, overhead expenses, and the method of setting piece rates. Chief of Ordnance Crozier remarked rather smugly in 1913 that:

> The Springfield Armory also uses in its very efficient manufacture many of the principles of the Taylor system, although they were not obtained from Mr. Taylor or his experts, but have been applied through many years, and lately at an increasing rate, by the officers of the armory.[653]

Springfield managers had probably always recognized that the scale of output was somehow relevant to these calculations, but now grew more explicitly concerned about identifying why this was so, and when to shift from day rates to piece rates and possibly back again, as output went up and down. After the Armory began production of an automatic pistol (model 1911), the annual report of 1914 remarked that only 2/3 of the piece work tariffs had yet been determined for the pistol, and foresaw an increase in output by workers then paid by the day, once they were paid by the piece.[654] The following year's report blamed the high costs of the M1911 pistol on its small-scale production in a factory set up primarily for making 1903 rifles, and noted that:

> The piece work tariffs on all operations involving the running of a group of machines by one workman are fixed upon the basis that the entire group is running. As production is decreased...it is impracticable to run the entire group and consequently the operator cannot make his rating at the tariff. Then either the tariff must be increased or the job put on day work. In either case the cost of the operation is increased.[655]

All in all, the report noted, the expense per item increased with lower output; since the direct labor charges did not fall proportionately to a fall in output, the total cost of each weapon rose even with the same efficiency in production, under the same accounting methods.

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[652] Hugh J.G. Aitken, Scientific Management in Action: Taylorism at Watertown Arsenal, 1908-1915.

[653] ARCO 1913, p. 14.

[654] ARSA 1914, p. 3, SANHS.

[655] ARSA 1915, p. 5, SANHS.

Although piece-work at the Springfield Armory long preceded Taylorism, and had not caused workers' discontent there, as Taylorism had at Watertown, it ran some danger of being tarred with the same brush when Taylorism fell into disfavor. The Army appropriation act of March 1915 prohibited time studies and premium payments (conspicuous features of Taylorism) in the work done under that act, which included work at Springfield Armory.[656] The 1916 appropriations act further prohibited dividing a job into component parts for separate timing, which was certainly a long-standing feature (in some sense of the concept "timing") of the procedure for setting piece rates at Springfield. However, a decision by the Comptroller of the Treasury distinguished between the premium payment system, in which a minimum wage was guaranteed and premiums paid additionally, and ordinary piecework, in which no minimum wage was assured in advance. The Controller decided that piece-work ***per se*** was not prohibited by the act.[657] Regardless of what the Controller had in mind in making this distinction between piecework and premium payments, we surmise that the difference between the two would also be perceived by workers as significant because of the difference in procedures for deriving the rates of pay. Piece rates were derived by dividing a "fair day's wage" by a "fair day's work," while premium payments were determined with a stopwatch.

When Congress appropriated money late in 1916 for a build-up of arms production at Springfield, the Armory found new workers only with difficulty, in face of a tight local labor market for skilled men. Of the 1,377 workers hired between September 1916 and April 1917, nearly half (608) resigned or were discharged again in the same period. When Springfield was authorized to offer overtime pay and instituted two ten-hour shifts in March 1917, it became much easier to hire men for the increased work load. The annual report for 1917 attributed the rise in cost that year, from $14.47 to $23.40 per rifle, to the higher wages and lower efficiency of inexperienced workers.[658] Wages were increased in December 1917 and May 1918.[659]

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[656] ARCO 1916, p. 817. Since most premiums were paid under a different act, for fortifications, the 1915 prohibition had little effect on premium payments, but Congress closed this loophole in 1916.

[657] Ibid.

[658] ARSA 1917, pp. 1-2, 5, SANHS.

[659] ARSA 1918, p. 8, SANHS.

During the participation of the United States in World War I, women entered the Springfield Armory workforce for the first time, as it more than doubled from 2,265 workers in June 1917 to 5,129 in June 1918. There were 235 women on the payroll in June 1917, generally employed in filing, inspecting, packing, and sorting, but also in some machine work.[660] By Armistice Day in November 1918, 748 women and 4,633 men were on the payroll, a ratio of 16% to 84%. Of those 5,381 men and women, 2,214 (41%) were dismissed by May 1919. The first to be let go were women whose families did not depend on their earnings, then women who were able to return to peacetime jobs; then men and women both according to their efficiency ratings, but with preference given to veterans among the men and to women who were the sole support of families whose men were still in military service. By July 1919 the percentage of employees who were women dropped to 6.4%.[661] Between July 1919 and July 1920, the civilian work force was about halved again. Among the retained employees, the high proportion of piece work helped preserve their wage levels.[662]

Retrenchment continued at the Armory from the end of World War I into the middle of the 1920s, as the number of civilian employees at Springfield Armory dwindled from more than 2,400 in 1920 to less than 250 in 1925 and the Armory's annual output of rifles dropped from more than 100,000 to less than 6,000 in the same period (See Table 6.4). Repair and overhaul of rifles and production of rifle components and appendages became relatively more important activities than production of whole new rifles. This was especially so in the years 1928-30, in which the number of employees rose again to more than 400, who produced fewer than 5,500 new rifles total each of those years, but repaired over 24,000. The proportion of the annual appropriation that was paid out in wages declined sharply from an average of 56.4% for the years 1920-1924 to 25.8% for the years 1925-30 (Table 6.4).[663] Nevertheless, although average monthly wages at the Armory dipped below $120 in 1922 and 1923, they were above $130 from 1925 through 1930. This compares quite favorably with the national average of around $114 per month for production workers in manufactured durable

[660] Ibid, pp. 1, 8-9.

[661] ARCO 1919, p. 15-16; Constance M. Green, "History of Springfield Armory," Vol. II, p. 4.

[662] Green, pp. 8-8a.

[663] These proportions were calculated by multiplying the figures in column j by twelve and dividing the products by the figures in column i, then averaging for the time-spans stated.

goods for the years 1923-1930.[664]

During the Great Depression of the 1930s, Springfield Armory workers were deemed lucky to have relatively secure jobs at all. Nevertheless, as the number of civilian employees grew from 966 in 1935 to 1,594 in 1939,[665] they also grew dissatisfied with their pay faster than the managers recognized. The Armory wage board made seven surveys of the work from 1930 to 1937, but re-viewed only 14 of the nearly 200 classifications of work. A visit in 1937 by a representative of the Inspector General revealed a large number of complaints, whereupon workers formed a new labor union, Lodge 431 of the American Federation of Goverment Employees,[666] and succeeded in obtaining a general wage survey. This resulted by June 1939 in increased wages for some 45 jobs.

At Springfield Armory's request, the Chief of Ordnance authorized such surveys of the local industries to take into account bonuses of various sorts with which the companies may have been augmenting the wages of their workers, in addition to their "straight day rate."[667] The Ordnance Department also required the Springfield wage board to reclassify all jobs at the Armory on a basis of three skill levels rather than the five to seven grades previously in effect for most Armory jobs. After 1938, as production increased, wages kept up with those for comparable work in local private industry, and opportunities for promotion increased in engineering and administrative jobs at the Armory. In 1938 the Wage Board rejected the idea of paying extra for work on a night shift, but in 1940 added five cents per hour to wages earned by night.[668] After 1936 the Armory changed over from the 1903 model rifle to the M1 (Garand) semi-automatic model. By January 1941, 126 piece-rate tariffs were in effect for the new operations; 120 of these were revised upwards by the end of 1941, while 88 new classifications were added.[669]

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[664] U.S. Census Bureau, Historical Statistics of the United States, Colonial Times to 1957, p. 92. This series gives average weekly earnings which, when multiplied by 52 and divided by 12, yield the monthly wages shown in our Table 6.1

[665] Green, table "Summary of Financial Statements 1935-39."

[666] A chapter of the National Federation of Federal Employees had formed at Springfield earlier in the 1930's, but it remained small and non-influential. Green, Vol. II, p. 69a-69b.

[667] Stewart to Dunn, June 21, 1939, in Green, Vol. II, Appendix II, pp. 82-84.

[668] Green, pp. 69a-d, 121-22.

[669] Ibid, pp. 122-4.

The Armory was better prepared for war production in 1941 than it had been in 1917. At the time of the Japanese attack on Pearl Harbor, the production quota of M1's was 1,100 per day; by July 1943 it nearly doubled to 2,100 per day. At the same time the workforce increased from 7,500 to 12-13,000. As in World War I, women were hired to help overcome the labor shortage induced by the draft; they constituted 20% of the workers by June 1942 and 43% by June 1943.[670] Despite this measure, the workforce declined in number to 11,300-11,800 in the second half of 1943, to 10,900 by June 1944, and to 9,400 by the end of 1944.[671] The continued shortage of skilled men led the Armory to install new equipment and plant layouts in some areas, notably in the production of M1 cartridge clips. It also managed to retrieve the services of a few men who were drafted by arranging for their return, as soldiers, through the Ordnance Department's Springfield detachment.[672]

At least one labor-saving measure in this period resulted in a cut in piece rates. In July 1944 the Advisory and Wage Control Division--presumably a successor of the old wage boards--noted that the time needed to straighten rods had been cut by one-third. Attributing much of this change to a change in the steel used, in heat-treating methods, and to other engineering changes, they lowered the piece rates for rod straightening accordingly. This precipitated a walk-out by rod-straighteners, who refused to accede to the engineering changes as a factor in the reduced time. They returned at the new rates after six days absence. (See below for more details on the ensuing labor dispute.)[673]

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[670] Ibid, pp. 147-51.

[671] Ibid, pp. 296-97; 482-43; 560-64.

[672] Ibid, pp. 482-3.

[673] Ibid, p. 580.

Table 6.4. ACTIVITY AT THE SPRINGFIELD ARMORY 1920-1930[97]

Fiscal Year Ending June 30	(a) Officers On Duty At One Time	(b) Civilian Employees Average For Year	(c) Yearly Rifle Output	(d) Yearly Rifles Per Employee	(e) Total Yearly Output Rifle Components & Appendages	(f) Total Yearly Rifle Repair and Overhaul	(g) Total Yearly Repair and Modification All Machine Guns	(h) Total Yearly Pistol and Revolver Repair	(i) Available Funding	(j) Average Monthly Payroll	(k) Average Monthly Pay Per Person	(l) National Average Monthly Wage in Manufactures
1920	7	2451	100,062	40.8	153,891	740,910	10,166	139,684	$6,865,534	$331,162	$134.73	
1921	9	1000	38,856	38.9	1,538,906	54,104	5,349	102,732	3,170,503	154,509	153.13	
1922	7	514	20,469	39.8	121,385	15,928	2,448	8,401	1,275,255	61,903	118.58	
1923	8	300	10,138	33.8	28,484	1,220	526	137	767,459	35,176	114.21	111.71
1924	7	257	8,542	33.2	4,474	5,352		2,184	751,510	33,365	126.38	111.97
1925	6	236	5,574	23.6	93,660	3,165	103	20	1,547,264	31,525	130.27	114.36
1926	7	253	8,916	35.5	117,545	3,351	5,131	207	1,905,185	34,385	132.25	115.31
1927	7	321	10,958	34.1	109,215	4,784	135	1,459	1,846,639	43,258	131.88	115.53
1928	7	353	5,484	15.5	440,203	24,424	52	24,424	2,117,451	47,646	132.35	118.04
1929	7	427	5,476	12.8	375,027	25,303	427	2,692	2,533,043	57,058	132.70	117.95
1930	7	471	4,375	9.3	747,186	27,260	1,968	10,267	2,732,267	63,236	132.29	107.34

Around the same time, a research program was initiated by the Control and Special Projects Department at the Armory, to take advantage of the fact that 90% of the manufacturing operations by now had piece-rates established by the Production Engineering Division. The Control Office proposed to use the record cards of the Production Engineering Division and of the Accounting Division to compare the actual time spent on manufacturing each component of a weapon with the times of operations ascribed by the piece-rate establishing process. Although the Control Office claimed that workers on day rates produced less than one-fifth of what they produced on piece rates, they were not given the resources "by the responsible authorities" to complete this research into the reasons for such discrepancies.[674] However, the study did allow for a rough gaging of the effectiveness of the non-productive labor (janitors, clerks, supervisors, set-up men) charged to each shop's expense. A standard for such indirect labor was created on the basis of the performance of the last three months of 1944, to be used as a measure of efficiency thereafter.[675]

War production began winding down before the end of World War II. After V-E day in May 1945 about half the workforce of 9,000 was dropped; of these 4,440 civilians still employed on V-J day in August 1945 were released in September, and by the end of 1945 there were about 1,700 left.[676] Returning veterans helped rebuild the workforce to more than 2,500 workers by the end of June, 1946, for re-manufacture of the M1 and manufacture of the .50" caliber machine gun. Of these, 1,450 were production workers, increased from 650 at the beginning of 1946.[677] Simultaneously, many administrative changes were made, with much consolidation, but the Control Section survived to continue making analyses of production costs, overhead, and efficiency.[678]

Post-1945 data on Armory labor and specialization is at best cryptic in available sources, but it is clear that during the 130 years after Roswell Lee acted as "Control Section," among his other responsibilities, the Armory had divided and specialized--many times over--the labor not only of its

[674] Ibid, pp. 640-42b.

[675] Ibid., pp. 778-80.

[676] R. J. Malcolm, "Springfield Armory/Historical Summary of Activities 2 September 1945-30 June 1951," SANHS.

[677] "History of the Springfield Armory, 1 January 1946 thru 30 June 1946," pp. 12, 30-32, 35, SANHS.

[678] "History of the Springfield Armory, 1 July 1945 thru 1 December 1945, pp. 4-8; Ibid. 1 Jan. 1946 - 30 June 1946, p. 29, both SANHS.

production workers but also of its management.

C. Working Hours and Hours of Work

Andrew Ure, the 19th-century English philosopher, lexicographer, and apologist of the industrial revolution, wrote that the main difficulty in bringing about the factory system

> did not lie so much in the invention of...mechanism...as in the distribution of the different members of the apparatus into one co-operative body ...and above all in training human beings to renounce their desultory habits of work and to identify themselves with the unvarying regularity of the complex automaton.[679]

At Springfield, achieving this identification among the armorers involved--as elsewhere--a period of revision in their expectations concerning time and its disposition.[680] The transition from desultory to coordinated effort by the armorers was intertwined with the issues discussed above of division of labor and wages, as well as the issues discussed below of work environment and labor-management relations.

Even as the wages at the Armory were on the whole good, relative to those at comparable manufacturing establishments, so were the working hours shorter. The official working hours at the Armory were ten hours a day early in the 19th century, when comparable jobs elsewhere required 11 or 12 hours daily.[681] When the work day was shortened to ten hours elsewhere, it dropped to eight hours in federal establishments (1868). In wartime emergency, however, the Armory reverted to longer hours and more than one shift a day, as mentioned above in connection with the Civil War, Spanish-American War, and World Wars I and II.

But the issues of how long the Armory was open per day and how long any armorer's work day should be were much more complicated than this. The progressively finer division of labor and predominant payment of wages by the piece from early on at Springfield Armory meant that an

[679] Andrew Ure, The Philosophy of Manufactures, p. 15.

[680] E.P. Thompson, "Time, Work-Discipline, and Industrial Capitalism," pp. 56-97.

[681] On this point, Deyrup, p.162, cites Louis McLane, Documents Relative to the Manufactures in the United States collected and transmitted to the House of Representatives by the Secretary of the Treasury, Report of 1833, Vol. I, pp. 280-281. In 1854 the work day at James T. Ames's nearby patent arms factory was 11 hours; see Superintendents of National Armories..., p. 67.

ambiguity remained long unresolved as to what an armorer owed to the Armory in return for his "fair day's wages." Was "a fair day's work" his effort during an average ten-hour work day, or was it the output of that average effort, even if he intensified the effort some days and went home early? Since some of the workers were paid by the day instead of by the piece, would not they resent the shorter hours of piece-workers who left early? What about the overhead costs to the Armory of heating and lighting the buildings in cold months and on dark days, if few men were actually present and working? Similarly, what about the wear and tear on the power system--water at first and steam later--if it were to be made available at odd hours for a few men? With steam power and its requirement of fuel, this was a more urgent consideration, but even with water power, whose reliability varied seasonally, it was important not to waste the ponded water when the flow was low.

Underlying such questions concerning the duration of work time and piece work was the suspicion that the Armory workers were "soldiering" on the job: if one could "make his rating" or produce his daily stint in less than a day, then why was not the daily stint higher and his piece rate lower? The issues were investigated on two major occasions in the mid-19th century, in 1841 and 1854. On those occasions they were also enmeshed with the issues, discussed below, of what rules of behavior should prevail at the national armories and whether they should have military or civilian superintendents.[682]

With artificial light so dim and expensive in the early 19th century, some variation in hours was imposed upon the Armory simply by the seasons. The hours of daylight grew short in the winter and long in the summer, so the working days of day-workers, which were supposed to average ten hours daily, were adjusted accordingly from eight hours in December to 11 1/2 in June.[683] In spring and fall, the working days were actually ten hours long, and before the 1840s the extra 1 1/2 hours in summer were not really required. Roswell Lee announced regular shop hours of 7 a.m. to noon and 1 to 6 p.m. in May 1816.[684] But the following November, as a concession to piece workers who wished to work early or late, in spite of the seasonally diminishing daylight he started opening shop

[682] Davies, Chase, and Tyler; Superintendents...

[683] Deyrup, p. 162.

[684] Whittlesey, Chapter 5; Dalliba, p. 543 confirms this for dayworkers April-Nov.

at 6 a.m. and closing at 8:30 p.m.[685]

Of 28 "Regulations for internal government of the Springfield Armory" as of 1836, four dealt with time, but those concerning the ten-hour day and the "keeping" or recording of "days and parts of day" for each worker referred only to those "employed by the day," not by the piece. The rule applying to all workers was vaguer: "it is expected of the workmen that they will be regular in their attendance and constant in the execution of the work assigned them unless prevented by indisposition or some other unavoidable circumstance."[686]

Barrel welders were in any case not expected to work ten hours because of their arduous, hot work. Under John Robb's supervision, "six hours was about as long as they could work...over anthracite coal fires." To avoid working in the heat of the summer days, "some of them would go to work... as early as 4 o-clock in the morning." Suggesting a daily stint, the welders "generally got the required number of barrels welded before 'knocking off.'"[687] Toward the end of Robb's superintendency, the piece-workers' self-determination of flexible working hours, plus other examples of Robb's supposed laxness, came under fire. A board appointed in 1841 to investigate working conditions at the Armory professed to be surprised when they visited that September, "to find that no regular hours were established for labor. Every mechanic, working by the piece, is permitted to go to his work any hour he chooses, and to leave off at his pleasure. In some instances the machinery at the water-shops has been kept running for the accommodation of a single mechanic; and in most of the visits of the board, though made in hours usually devoted to labor, these shops were found nearly deserted."[688]

John Chase, builder of the Massachusetts manufacturing villages of Cabotville and Holyoke, was a member of the 1841 visiting commission. He later said that in his opinion the "...average labor of piece workmen throughout the Armory would not come up to six hours a day of good faithful

[685] Whittlesey, Chapter 5.

[686] Rules 8th, 9th, and 19th, "Testimony.." p. 142, 143. The other time-related rule, the 18th, concerned the length of leaves of absence a foreman could grant (three days in 1836, reduced to two by 1854).

[687] Robb, in "Testimony..," p. 18.

[688] Davies, Chase, and Tyler.

service, as mechanics should work" and "...it would not require more than three or four hours work per day for some of the armorers to earn a reasonable amount at the prices then given...I think that some of the workmen could have done more work than they did when the Commissioners were timing them."[689]

When the civilian superintendents Roswell Lee and John Robb were succeeded by Ordnance officer Major James Ripley, their explicit rules were not changed, but attention was paid to enforcing all the workmen's actual attendance during regular hours. John Chase advised Ripley that it was "...customary to keep the time of piece workmen and men who worked by the job in manufacturing shops generally...in order to establish prices...and in case a person did not complete his piece or job work, in order to know how to make a settlement."[690] Joseph Weatherhead, who had 26 years of experience at the Armory including a period as master armorer, said that during the former civilian regime the bell rung for commencement and end of work was a signal for day workers only, while piece workers were "...allowed to come and go as they pleased, provided they were not absent several days in succession without permission." Under military superintendence, however, "...a well regulated time system has been established both for those who work by the day and those who work by the piece, and so graduated as to average ten hours per day through the year." Now not only were bells rung for commencing and leaving work at morning, mid- day, and night, but the day was also divided into quarters, and with some exceptions for welders, "..all are required to observe quarter time..," that is, to come or go only when a quarter-day was up. Supervisors now "...kept time.." to show how long a day-worker was employed on tools or machinery, and how long it took a piece-worker to "...perform the number of pieces he has accomplished." Weatherhead added that "Those rules were strictly enforced and observed, and I deem them a very decided improvement on the old system."[691] Work returns and payrolls show that quarter-days were indeed credited to the workers, and that the same individual sometimes did day work as well as piece work in a single month.

Other managers and workers, however, disagreed, such as Benjamin Moor and Armistead Hobbs, respectively former master armorer and former workman at Harpers Ferry Armory, who were both

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[689] "Testimony..," p. 100.

[690] Ibid.

[691] Ibid, p. 83.

critical of this imposition of time discipline on the piece-workers there. In testimony before the investigating committee of 1854, Moore considered it counterproductive to keep a worker in the Shop if he had finished "his day's work" part way through a quarter of the day.[692] Hobbs said "I conceived it none of the commandant's business what time I should quit, if I kept my work full."[693]

These mid-century critics, however, also acknowledged the exigency of the overall production system. Thus, Hobbs readily agreed that if he had actually fallen behind in his work it would have hindered the work of others in the shop: "If I neglected my work, it would throw the others out."[694] Similarly, Joseph C. Foster, an artisan for twenty years at the Springfield Armory, denied that keeping the water power running for only a few workmen caused any serious expense to the government under normal conditions: "A water wheel would last longer by being kept running...The expense was not a cent a day." But he noted the need for accommodating to a low water flow: "When the water was in a condition to be affected by the men going to work at different periods and knocking off at different periods, the men were made to go to work together." And, he commented, "There was no steam used then...As it is now, worked by steam, the men should go to work at the same time."[695]

Although the Armory resumed civilian superintendence from October 1854 until March 1860, the requirement of full working days even for piece workers apparently remained established; the continued use of steam power on Armory Hill and the consolidation of all the water shops at one location may have helped make clear to all the necessity of coordinating individual actions more closely with the "unvarying regularity of the complex automaton."

During the Civil War emergency the hours of work at Springfield increased to two 10 1/2-hour shifts daily.[696] Afterwards, as mentioned above, the shortening of federal workers' official length of

[692] Ibid, p. 81.

[693] Ibid.

[694] Ibid.

[695] Ibid, p. 56.

[696] Whittlesey, Chapter 7.

day to eight hours in 1868, which was intended to save money for the government, reopened the confusion over time differences for day workers and piece workers at the Armory. After a short windfall period of being paid the same wage for a shorter day, the day workers had to work two hours overtime to keep their wages as high as before, while piece workers kept their wages up by working harder during the eight hours, and then went home.[697] Following unusually vociferous protests, the President proclaimed in the spring of 1869 that wages would not be reduced under the eight-hour law, and the government later compensated day workers who had lost pay in this episode.[698]

A discrepancy in hours recurred, but changed direction. In 1881, the Ordnance Office felt the need to inquire of the arsenals what their practice actually was. Springfield Armory replied that clerks (who were day workers) worked 7 to 8 hours, but shop workers (mostly on piece rates) and their foremen (paid by day) were again working ten hours daily.[699] In 1884, Springfield Armory workers signed up for a ten-hour day in spite of the law,[700] but in 1892 a Congressional Act explicitly limited all laborers and mechanics to an eight-hour day, except in times of emergency.[701]

The Spanish-American War provided such an emergency in 1898. As the work force shot up to 1,839 by the end of June, in March a second work shift was added except in the filing and assembling shops, which were thought to require daylight. A third shift was considered but rejected in favor of lengthening the two shifts to ten hours, and in some cases eleven hours per worker. In August the hours per shift were reduced back to eight, and more men were hired, especially for the night shift, to keep up the level of output.[702] In World War I, two ten-hour shifts were begun in March 1917, totaling 110 hours per week, or, implicitly, five 10-hour days plus one 5-hour day per man (or woman, see previous pages). The night shift was lengthened to eleven hours in October

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[697] Benton to Treadwell, February 15, 1869, RG 156/21.

[698] Deyrup, p. 206-7.

[699] Responses to Ordnance Office inquiry August 17, 1881, RG 156/21.

[700] Deyrup, p. 207.

[701] Springfield Armory Post Order 37, August 22, 1892, SANHS.

[702] ARSA 1898 in ARCO 1898, pp. 86-89.

1917, and production on Saturday halted to allow more time for maintenance of the machines.[703] After the war the normal work week of 48 hours was resumed.

Besides the eight-hour work-day, by 1911 the Springfield Armory workers, as government employees, were allowed 27 1/4 days of paid leave or holidays per year.[704] Presumably as a means to spread the work around more widely, the 40-hour week was inaugurated during the Great Depression from 1934-1940, and 42 days of paid annual leave were allowed, but in June 1940 the work week was lengthened again to six eight-hour days, with time-and-a-half pay for overtime beyond 40 hours.[705] As World War II wore on after December 1941, the Armory's much-expanded workforce declined in size as the order for M1 rifles was cut back, and in 1944 resistance grew to the war-time 48-hour week and to work on holidays.[706] This reflects a significant turnaround in Armory workers' relationship to wages and work time since the 1880s, when the workers had clamored for six ten-hour days from their unwilling government employers.

D. Work Environment and Behavior

Besides wages and hours, a third component of recognized concern to modern industrial workers is the safety and healthfulness of their working conditions. At Springfield Armory this explicit concern seems rarely to have entered the record before the twentieth century. However, other issues related to the work environment were important there in the nineteenth century. At Springfield Armory, as elsewhere, it took time to establish recognizably modern distinctions between on-the-job and off-the-job behavior by the workmen. The Armory grounds and armorers' time were both initially relatively permeable by persons and activities that were later declared ***non grata***. These were loitering, getting drunk, reading newspapers, singing hymns, buying groceries, spitting tobacco juice, smoking, and conversing on non-work topics.

After nine months as superintendent, Roswell Lee issued regulations in March 1816 that proscribed

[703] ARSA 1918, p. 2, SANHS.

[704] ARCO 1911, p. 22.

[705] Green, Vol. II, pp. 117-18.

[706] Ibid, pp. 416-17.

riotous behavior, drinking, and conspiracy against officers of the Armory. He provoked all three when he found two men wrestling in one of the shops and fired them on the spot.

> ...as was the custom they got some rum to pay their clearance and invited all hands out to the "liberty pole" in the center of the grounds to drink. There the men resolved that if they couldn't have any liberty they wouldn't have any "liberty pole" and went to work to cut it down.

When Lee sent the master armorer, Adonijah Foot, to disperse the men, Foot

> ...was told by one man swinging an axe to look out for his legs...Finally the Colonel himself went out, and...they desisted. Colonel Lee admitted afterward that he was hasty in the matter, though on the whole he thought it resulted in good to all concerned.[707]

Lee apparently settled for keeping liquor out of the workshops themselves, but not off the Armory grounds: the custom of one man standing the others to drinks all day remained outside the shops or in one of the coal houses with Lee's tacit permission.[708]

Under Lee's successor, John Robb, rule #21 also provided dismissal both for "...the introduction of..any kind of intoxicating liquor into the shops or upon the grounds contiguous thereto" and for "..any workman appearing at his work in a state of inebriation."[709] Robb claimed it was only once violated during his tenure (1833-41),

> ...and that was a case of intoxication. I suspended the offender; but upon his becoming penitent, I reinstated him, and also appointed his son. He turned out to be a most excellent man--so much so, that I increased his wages...[710]

Robb, a political appointee, was notoriously easy-going, according to later opinion, but at least

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[707] Alfred Booth, 1868, quoted in Chapin, 1893, p. 249, 251.

[708] Whittlesey, Chapter 5.

[709] Superintendents..., p. 145.

[710] Ibid, p. 15.

drinking spirits or beer in the shops was not obvious to the visiting commissioners of 1841.[711]

What shocked those commissioners was the "...reading of newspapers during the ordinary hours of labor," which, they wrote indignantly, "...appears to be so common a practice as not to be deemed improper; for in several instances the reading was continued even during the inspection of the board."[712] Robb acknowledged that he allowed letters and newspapers to be delivered to the work-men at their shops, but denied he ever found them "...consuming time in reading etc. to the detriment of the public interest."[713] Nevertheless, after Robb's departure a rule was added to forbid "...the reading of newspapers etc. in the shops during working hours."[714]

According to Joseph Weatherhead, during Lee's and Robb's superintendence, "...loafers and beggars were freely admitted to the shops...and were not put out unless they should create some disturbance,"[715] and newsboys, "...marketers, butchers, dealers in fish and provisions or farm produce...came and went as they pleased. In fact the Armory shops appeared a good provisions market."[716] In Robb's testimony however, "There being no market in Springfield, the butchers were in the habit of passing by the shops, when the men would step out and buy a piece of meat and come in immediately."[717] Under Superintendent Ripley's regime, Weatherhead as master armorer

> ...forbade carriers standing about the gates to deliver papers to the armorers, but did not forbid them out in the middle of the street; and I forbade the workmen from trafficking about the gates in any way. I understood the rules of Col. Ripley to extend to the exclusion of private business operations in and about the shops, including the walk on the outside of the fence.[718]

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[711] Ibid, p. 109.

[712] Davies, Chase, and Tyler.

[713] Superintendents..., p. 18.

[714] Ibid, p. 144.

[715] Ibid. pp. 83, 97.

[716] Ibid. p. 83.

[717] Ibid. p. 18.

[718] Ibid. p. 96.

Ripley's construction of an iron fence around the Armory Hill site undoubtedly helped in the enforcement of these new unwritten rules excluding persons from wandering in who might in one way or another distract the workmen from their work.

Among the other work-time practices by workmen that were tolerated during the years of civil superintendence but deplored by Joseph Weatherhead, in addition to riding out in horse and buggy, loitering, lounging and napping, was that "a party of musical or devout ones would occasionally group together and sing a few psalm tunes."[719] Although "...religious or political controversies in the workshops" were "expressly forbidden" in Robb's rule #20,[720] singing hymns seems to have been a way of expressing religious feeling nevertheless.

Rule #13 under civilian and military superintendents alike enjoined the various "inspectors"--later, "foremen"--"to see that each workman keeps his bench, window, and windowsill neat and clean and his tools in good order,"[721] but it was not until the mid-1840s that spitting (a habit of tobacco chewers) became an offense punishable by reprimand or discharge, and spit boxes, which when used at all had frequently been left filthy, were removed.[722]

Objections to the enforcement of such rules became embroiled with objections on other grounds to military superintendence, particularly in the person of James W. Ripley, the one pre-Civil War military superintendent at Springfield Armory. Some of the objection was not to the existence of such rules, but to lack of explicitness about them. In 1854 testimony was taken before a House of Representatives investigating committee that at Springfield rules were not "...posted up or in any manner accessible" so the men "...never knew under what rules they were working" and that the men were "...in a constant state of alarm for fear that they might unconsciously do something which the commandant might construe into a violation of some of the rules."[723] The then-Secretary of War,

[719] Ibid. p. 85.

[720] Ibid, p. 144.

[721] Ibid, p. 143.

[722] Ibid, pp. 39, 112-13.

[723] Ibid, pp. 39, 55.

Jefferson Davis, defended the practice of military superintendence by pointing out:

> There is no material difference between the rules and regulations for the government of the operatives employed at the national armories under the respective superintendencies of civilians and of ordnance officers...the rules, under both modes of superintendence, are believed to have been such as are requisite for the proper, efficient, economical, and systematic management of any large manufacturing establishment, and are understood to be no more stringent than those in existence in large private factories... The essential...difference between...the two modes of superintendence, consists in the extent to which the regulations for their government have been enforced. A strict compliance with them is now required... [724]

Following a period of civilian superintendence from 1854 to 1860, during which, it is thought, discipline as to working hours and behavior was generally maintained, a military superintendent, Capt. A. B. Dyer, was appointed. After war broke out, under an oath required of the workers to "...well and faithfully perform all the duties which may be required by law," Dyer forbade loitering, smoking, reading, and peddling in the shops, and limited conversation to the work at hand.[725]

As mentioned above, the safety and healthfulness of working conditions at the Armory seems to have been--with the exception of the spit boxes--an issue of little overt concern to management or workers there until World War I, when first-aid stations were instituted, under an inspector responsible for keeping the plant "sanitary," and a campaign was inaugurated to educate workers on safety.[726] In 1938, a safety council was set up among shop foremen and department representatives, to induce the reporting and treatment of minor injuries, and men in each shop were trained in first aid. Safety devices were installed on some machines. The campaign succeeded in reducing time lost to accidents and infections in the period 1938-42 by about one-half.[727]

Other health-related amenities noted in the official records of the Armory were, in 1910 and 1911, the conversion of the old barrel-proving building at the Watershops into a bath house, conversion of

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[724] Ibid, pp. 133-34.

[725] Whittlesey, Chapter 7.

[726] ARSA 1918, p. 9, SANHS.

[727] Green, Vol. II, p. 118-19.

other former factory space into a lunchroom, and installation of new drinking fountains everywhere.[728]

If accident or sickness did disable them for more than 15 days, from 1908 the Armory workers, as government employees, were granted full pay until recovery, and if they died, care was assured for their dependents.[729] This was not a brand-new concern, but one for which Roswell Lee had proposed an accident and sickness temporary relief fund in 1817, from contributions of $1 a year by each worker and from the forfeitures they paid for spoiled work.[730]

E. Military and Civilian Shop Management

The anomalous situation of Springfield Armory as a military-owned and civilian-manned manufacturing establishment led to intermittent controversies throughout Armory history, and gave a peculiar cast to the relations between management and workers. Worker-boss disagreements were sometimes seen as citizen-soldier conflicts, whose resolution could be channeled through Congress instead of being restricted to the labor actions more usually available to workers in private industries. The potential for Congressional intervention persisted in civilian as well as military superintendencies, and in fact proved somewhat more forceful under civilian superintendents. Direct appointments of the latter by the Secretary of War were more subject to political considerations than were choices of officer commandants made by the Chief of Ordnance. Although also subject to the Secretary of War's authority, the chief of ordnance and his subordinates were Army Ordnance officers, shielded (albeit incompletely) from civilian pressures by military customs, procedures, and allegiances.

As we discuss in section F of this chapter, however, the latent powers of civilian workers and military-appointed superintendents or commandants rarely erupted into serious disputes. In addition to the relatively steady employment and benefits enjoyed by government employees, the importance of civilian authority and skills within Armory shops was a major factor in this generally tranquil record. The structure of Armory shop administration established early in the 19th century, under

[728] ARSA 1910 p. 5, SANHS; ARCO 1911, p. 48.

[729] ARCO 1911, p. 22.

[730] Green Vol. I, p.34

civilian superintendents, persisted undisturbed until the introduction of the Krag rifle. Military commandants lacked either the need or ability, or both, to disturb efficient working relationships. The difficulties associated with producing the Krag prompted Colonel Mordecai to use his small cadre of subordinate officers more aggressively than did his predecessors, but the Ordnance Department's small size restricted military involvement in Armory management except during the two world wars. There were rarely enough officers available to oversee Armory shops with any regular, close attention, and officer re-assignments were often so frequent that few of them could become as familiar with shop procedures as civilian supervisors.

From the earliest period of Armory musket manufacture, there were three distinct tiers of authority administering workers in their shops. At the top, the superintendent or commandant was responsible for achieving Ordnance Department goals and, after 1815, managing funds and expenditures. Beyond regulating matters of decorum and work hours, however, the Armory head appears rarely to have dealt with shop affairs directly.

The master armorer, a civilian subordinate of the superintendent or commandant, occupied the second tier and had, until 1894, the most important role in managing production. The Armory heads recommended men for this job which, unlike all others at Springfield, was mandated by the 1794 act creating the national armories and required the approval of the Secretary of War or, after 1815, his subordinate, the Chief of Ordnance. With the aid of a few clerks, the master armorer acted as a combined planning, engineering, and accounting department. He was responsible for organizing the distribution of work and materials among shops, recommending and overseeing the use of mechanical equipment, collecting monthly records of output for transmittal to the Armory head, and acting as chief and final inspector of finished weapons.[731] Although not necessarily a gifted mechanic himself, he had to be thoroughly familiar with arms-making at Springfield, and at least directed the creation of new gage and tool designs as necessary. The Armory machine shop, under the direction of a master machinist until perhaps the Krag era, built or modified machine tools, sometimes with input from the master armorer.[732] By the later 19th century, draftsmen under his

[731] Superintendents of National Armories..., pp. 34, 141-45.

[732] Our sample of Armory work returns and payroll records, which included most available information for the years 1804-16, 1820, 1825, 1830, 1835, 1840, 1843, 1850, 1856, 1860, 1864, 1878, and 1898 (end of series in National Archives), did not reveal much information about the chronology or role of the master machinist's job.

direction handled much of the latter task.[733]

The third tier of shop administration consisted of fluctuating combinations of foremen and inspectors who managed production in each shop. Because of the numerous stages in musket manufacture, the small scale of early Armory facilities, and the accidents of Armory geography, manufacturing operations were originally diffused among six or more different shops. Steam power and the construction of the Federal Square shops allowed for some spatial concentration of activities, as seen in Chapter 2, but Armory shops operated as rather autonomous units into the early 20th century, organized around the general character of the work (e.g., milling, filing, stocking, forging). In each shop, one or more supervisors was responsible for direction of work, inspection of output, and monthly accounting to the master armorer of raw materials and finished components. Shop supervisors also drew up requisitions, based apparently on their own assessments of shop requirements, until the new procurement and planning systems introduced in the decade before World War I (Chapter 5).

The number, titles, and authority of shop supervisors, directly responsible to the master armorer, shifted several times before c1850. There were essentially two main supervisory roles: acting as foreman, and inspecting, with the latter including marking and recordkeeping. Until about 1845, both roles were sometimes held by the same men, variously referred to as assistant master armorers, assistant armorers, foremen, inspectors, or sub-inspectors. Before about 1830, assistant master armorers governed the Hill shops, and foremen ran the Water shops, but the jobs were probably very similar. An 1842 law providing annual pay for inspectors created some confusion, since Armory foremen were paid by the day or month. The law was evidently intended more for inspectors of contract arms, a class of men separate from Armory employees after 1831. By the late 1840s, however, the scale of operations evidently warranted dividing the supervisory roles in one shop among two or more men, with the foremen having senior status in a shop. All Armory inspectors became foremen in 1852, with any assistants called assistant foremen. During the great expansion of operations in the Civil War, all three positions--foremen, assistant foremen, and inspectors--flourished in the populous shops, as questions of terminology were dropped or forgotten. This same

[733] ARSA 1893, in ARCO 1893, p. 200.

situation pertained until the bureaucratic and sometimes physical separation of foremen and inspectors introduced in the early 20th century, to avoid conflicts of interest and loss of quality control (Chapter 3).[734]

It is important to recognize that in 19th century Armory shops, civilian supervisors directed and inspected the work of their armorers, adding to their autonomous control of the shops. With little opportunity for detailed shop management by the master armorer, this system also provided the armorers with more freedom, and opportunities to influence or even intimidate the men most responsible for inspecting their work and determining their pay. There appears to be little documentation of such conflicts of interest, but scattered references indicate the problems were persistent, though perhaps rarely virulent.[735] If Armory superintendents or commandants could not easily penetrate the nest of shop life, then occasions for worker dissatisfaction were understandably infrequent. Until the arrival of Col. Mordecai in 1892, these occasions concerned personal prerogatives and pay more than direction of shop activities.

Before the Civil War, the Armory superintendents were civilians (though some had been Army officers)--except for the tenure of Ordnance officer James W. Ripley from 1841 to 1854. Ripley's style of management was felt by many in and around the Armory to be too overbearingly military. He was regarded as "aloof," "haughty," and "austere" in manner.[736] Ex-governor John Steele of New Hampshire said that at Springfield "...men are treated more like serfs than freemen."[737] Former master armorer Benjamin Moor criticized the military superintendents at Harpers Ferry for their lack of practical mechanical experience and added that "...the workmen do not feel well under a man with military command. To a civil superintendent he can speak as a fellow-citizen; to a military man he could not."[738] Former superintendent Robb said that where civil superintendents listened to workers' complaints, military superintendents turn them off and rebuked them, which inhibited not

[734] Superintendents..., pp. 51, 66, 69, 141-45; Armory work returns and payroll records, RG 156/1371 and 1379.

[735] e.g., Davies, Chase, and Tyler; Allin to Lee, January 25, 1830, RG 156/ 1365.

[736] John H. Steele testimony in Superintendents..., p. 40.

[737] Ibid.

[738] Ibid. p. 13-14.

only their complaints, but also their valuable suggestions for improvements in machinery.[739]

In defense of military superintendence (and of himself), Ripley said a civilian superintendent owed his appointment to political influence and would therefore not enforce work rules because he would fear losing his popularity and his office "by political influence which the armorers can bring to bear against him." He said a military officer, who cannot be deprived of his commission except by court-martial, has no such fear of the "clamors of the armorers," and is in fact gratified in such a case to be transferred to a different post. He added that "The question, in my judgment, is simply whether the superintendent or the workmen shall regulate the management of the armory."[740]

After hearing testimony from "...the friends of the civil and of the military systems of superintendence respectively,"[741] Reuben H. Walworth of New York, one of the commissioners on the House special committee on the subject in 1854, wrote, diplomatically enough, that:

> The citizens of a government like ours are naturally, and very properly, jealous of military power...Men are so constituted, that the same thing may be done by a civilian placed in authority over them without exciting any dissatisfaction, which if done by an officer of the Army, under similar circumstances, the same persons would become dissatisfied with, and complain of it as military tyranny and oppression. It is less difficult, therefore, for a civil superintendent to maintain a proper degree of authority over the workmen at the Armory, without creating excitement and discontent, than it is for a military superintendent to do so...the true interest of the gallant officers of our little army, as well as the interest of the armorers and of the public, requires a return to the former system of superintendence [by civilians]...[742]

This was done, and James Whitney became the superintendent at Springfield for a quiet and competent term. From the Civil War onward, however, not only was the Armory superintendent an army officer, but for the first time newly created subordinate positions were filled by junior officers, making for a greater military presence than before. A military guard detachment was organized in 1861, and assignment of administrative duties to such junior officers grew after 1864. In 1882,

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[739] Ibid, pp. 19-21.

[740] Ibid, p. 177.

[741] Ibid, p. 212.

[742] Ibid, p. 218.

civilian Edward Ingersoll, who had been storekeeper/paymaster since 1841, was replaced by officers who were given authority over Ordnance and Quartermaster property.[743] None of the responsibilities given to officers from the 1860s to the early 1890s significantly enlarged the commandant's authority over workers or their shops, however. Subordinate officers, who in a few cases stayed at Springfield for long periods, instead engaged in experimental work (Chapter 8), learned about small arms manufacture, and to some extent assisted the commandant with his usual responsibilities.

There were rarely more than a handful of officers at Springfield. When Colonel Mordecai, frustrated by the difficulties of early Krag rifle manufacture, tried using his officers to exercise greater control over the seven shops operating in 1894, he had to make do with three men. Mordecai's manufacturing program, given more attention in Chapter 7, included three basic administrative changes which gave him more direct control over the shops. First, he took the opportunity of Master Armorer Samuel Porter's death in June 1894 to eliminate the master armorer's position, with the concurrence of the Secretary of War. Second, he used his officers to replace some of the master armor's administrative functions, requiring foremen to receive Mordecai's orders, as conveyed by his officers, prior to doing any work other than current repairs. Each officer was assigned two or three shops to oversee. Finally, he had the foremen assume the master armorer's responsibilities for selecting and adapting machines, tools, and fixtures for the work required.[744] Mordecai also replaced a number of foremen, assistant foremen, and some older workers.[745]

Mordecai's administrative changes were relatively dramatic, and represented the most potentially explosive civilian-military confrontation at the Armory since Ripley's command. There was, to our knowledge, no explosion. The transition was peaceful, if eventful, perhaps because Mordecai left the basic structure of Armory shop organization alone. Despite his concentration on introducing new manufacturing methods (see Chapter 7), making the Krag required many suggestions from Armory workers and foremen, as well as the presence of officers in nominal charge of shops for the first

[743] Whittlesey, Chapter 7.

[744] Springfield Armory Post Order No. 36, June 22, 1894, and No. 49, September 1, 1894, SANHS; ARSA 1894, in ARCO 1894, p.54. Mordecai made no mention in ARSA 1894 of how he replaced Porter's role in new gage development.

[745] ARSA 1894, in ARCO 1894, p.53.

time. Excessive disruption of traditional shop organization, let alone removal of many workers, could have easily resulted in the failure of Mordecai's mission to make the Krag. Aside from his insistence on foremen keeping daily time records for each worker, rather than each worker keeping his own records, there is no evidence that he changed the inspection system or attempted to regulate worker behavior beyond the regulations in effect when he arrived.[746]

The use of officers to coordinate shop work with the commandant continued until sometime in the 1920s, when the practice apparently atrophied temporarily. The number of officers grew in wartime and diminished in peacetime, as did the over-all work force. After World War I, the Army contingent of 50 officers and dropped to 23 officers by July 1919, and to 9 by July 1920,[747] while ballooning again from 9 in 1939 to about 50 in 1941. Between 1937 and 1941, the practice of joint operation of an officer and civilian in supervising Armory shops reappeared. Some workmen reportedly distrusted this arrangement, and later, during World War II, the appearance of uniforms on the officers was seen by many civilian workers as an attempt to "overawe" them.[748] As discussed in the following pages, this civilian-military controversy flared toward the end of that war, but the problem was limited to a small number of newer workers.

Increased control of Armory management over traditional shop autonomy finally came not from the presence of a few officers, but from the growth of new materials accounting, planning, and inspection systems in the early 20th century (Chapters 3 and 5). Centralized management of requisitions and job order planning (c1908-18) reduced the power of foremen to control the pace and sequence of work in their shops. Independent inspectors, deliberately separated from the men whose work they evaluated after c1907, probably introduced more control over workers' pay than the occasional tortuous calculation of piece rates.

These new systems were the beginnings of far more elaborate Armory bureaucracy, as the planning and management functions of the master armorer grew into several departments. The master armorer's position was revived for a time (1909-20), with responsibilities including inspection of

[746] Springfield Armory Post Order No. 30, August 30, 1895, SANHS.

[747] Green, Vol. II, pp.8-8a.

[748] Ibid, pp. 108-111, 438-41.

gages and tools made at the Armory,[749] but by 1911 "...the introduction of modern methods of shop management" led to introduction of a planning room and engineering division which probably made his job increasingly obsolete.[750] One man could not run many departments. Officers gradually took over some Armory departments after 1930, including Research, Manufacturing, and Inspection, although the limited number of available ordnance officers in peacetime meant that civilians occupied most of the new management posts, even within departments with military chiefs. The proliferation of bureaucracy reached a point where periodic coordination of production efforts was required, especially after World War II when Ordnance Department demands for more uniform management systems increased. It is unclear how these developments affected shop administration, although they sometimes exacerbated manufacturing problems.[751] Division of responsibility is not always as beneficial as division of labor.

F. Labor Disputes and Union Activity

There were few labor disputes of enough importance to provoke collective action by workers at Springfield Armory. Instead, the workers seemed to take into their stride the complications of piece rates, varying hours, and changes in management, to say nothing of the fluctuations in scale of production between the times of peace and war.

After the "liberty tree" incident in 1816, in which Roswell Lee's firing of two fighting workers for behavioral indiscipline led to a spontaneous and bibulous protest demonstration in Armory Square, there is a long hiatus in the record of labor unrest until late 1832, when armorers disputed wage cuts that had been recommended by a wage board in response to deflation. On this occasion they chose a committee headed by bayonet forger Elizur Bates (who later became master armorer for three years) to take their case in person to the Secretary of War in Washington, and won their point with the aid of the local Congressman, who was a kinsman of Bates. This channel of conflict resolution by way

[749] ARSA 1910, p. 3, SANHS.

[750] ARSA 1911, p. 4, SANHS. Annual reports from the 1905-17 era are remarkably casual about introduction of new bureaucratic divisions, perhaps because these divisions began on a very small scale. The roles of the planning room and engineering division were not defined in 1911.

[751] In 1951, for example, a committee of staff from the Production Engineering, Manufacturing Inspection, and Production Planning branches met to resolve problems arising from recommendations for tooling changes beyond the capacity of the tool-making facilities; SAHS 1 July 1951 - 31 December 1951, SANHS.

of political influence in Washington remained open, and was perceived by superintendents and workers alike as setting limits to superintendents' scope of control over armory procedures.

After all, armorers who lived in Armory housing on Federal property were not entitled to vote, but the armorers who lived in their own homes frequently became active and respected citizens of the town and, naturally, participants in local and national politics. The Congressional investigations of the Armory in 1841 and 1854 were complicated by other issues as well, but may be seen at bottom as attempts, respectively, to weaken and to strengthen this channel of indirect control by the armorers over the conditions of their employment.

After the Civil War, the armorers found themselves in a growing category of federal government employees, which was subject to across-the-board Congressional action that did not always suit the local conditions of work at the Armory, such as the law limiting working hours to eight a day. As we have seen, the armorers somehow managed in the 1880s to get an exception allowed so they could work ten hours a day. Armory correspondence in mid-summer 1892 shows that the Congressional channel was still functioning: when Armory workers in Springfield suspected that the "customary" two-week closing of the shops at the end of the fiscal year for inventory and clean-up would be followed by a major reduction in the workforce or work hours, they told their local Congressman, who promptly wrote to the Chief of Ordnance about it, who in turn wrote to the Armory superintendent, Colonel Mordecai, for explanation.[752] Similarly, when the practice of piece-work was threatened by provisions of the 1915 and 1916 appropriations acts, an exception was made by the Controller General--surely not against the desire of the Armory workers--to allow the type of piece-work prevalent at Springfield.

By this time, however, a tentative move toward a labor organization of more usual and less <u>ad hoc</u> type had begun at the Armory: the 1912 Annual Report of the Chief of Ordnance took note of the recently provided lunchroom as a meeting place for <u>two</u> unnamed associations of workmen.[753] It was not until the early 1930s, however, that a union was actually named--the National Federation of Federal Employees, local #101, -- and it was small and inconsequential. Following the revelation in

[752] Mordecai to Flagler, 7/8/92, and Lodge to Flagler, 7/13/92. RG 156/21.

[753] ARCO 1912, p. 43.

1937 of widespread worker dissatisfaction with wages, workers formed a new union, Lodge 431 of the American Federation of Government Employees (AFGE), which differed from most other American Federation of Labor units in being organized on industrial rather than trade lines. Any civilian employee could join, and it resisted attempts by trade unions (e.g. electricians) to move in, by arguing against splitting the ranks of the workers. As mentioned above, this union succeeded in getting an employee representative to accompany the investigations of the wage board that conducted a general wage survey and obtained increases for some 45 jobs by June 1939.[754]

Several years later, well into World War II, several disputes between workers and management arose at the Armory in which the AFGE Lodge 431 played a part. The union believed that, in issuing orders to civilians, the uniformed officers at the Armory were overstepping the boundaries set by Civil Service rules. The union itself, however, was not universally acknowledged as the civilians' representative in negotiations with management. The longer-employed supervisors, who were organized as the "20-year Club," tended to prefer relying on Congressional and Civil Service protection, and to put more faith in getting amendments passed to laws affecting all government plants. The managers looked askance at the AFGE, whose meetings in 1944 drew attendance of about 200 but which claimed 5000 paid-up members. It evaded submitting a roster of membership, while the other smaller union, the National Federation of Federal Employees local, did so, showing a membership of about 145.[755] Management felt that any union should play an advisory role only, since legislation and Civil Service rules left so little scope to the Armory itself for determining its own conditions.[756]

After proposing formation of a Labor-Management Committee in March, 1944, the AFGE subsequently rejected it when the management insisted on including representatives from the other union, AFFE, and the 20-years Club, and would not give AFGE more weight on the committee. This left them to rely on direct representations to the Commanding Officer, and on newspaper publicity. The issues at stake were management fairness in requesting draft deferments for individual Armory men, and how much weight to give seniority in making inter-department transfers and promotions.

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[754] Green, Vol. II, pp. 69a-b.

[755] Ibid. p. 441-42.

[756] Ibid, pp. 442-3.

The Works Manager, Lt. Col. Huth, was accused of favoritism in promoting a certain foreman of lesser seniority to civilian head of Manufacturing Inspection. The AFGE went to Washington to appeal to the Chief of Ordnance, who upheld Huth's decision.[757]

Despite having lost face in this fight, the AFGE leaders took on the task in mid-summer 1944 of representing the rod-straighteners who had (illegally) gone on strike for six days to protest a cut in the piece rate for straightening rods, mentioned previously. They wanted their work records cleared of bad marks due to their strike, but the Commanding Officer refused to do so, and the Chief of Ordnance also rejected their appeals. The AFGE then broadened the attack through the press by charging waste and mismanagement at the Armory, and threatening to carry the campaign to the House Committee for Military Affairs unless the Ordnance Department investigated the situation. An investigation by the Ordnance Department ensued, even though the AFGE attempted to retract its demand for one, but the investigation did not support the charges.[758]

In the course of this dispute the Commanding Officer died and was replaced, but the new one also ran afoul of the AFGE late in 1944 in his handling of a request by 46 foremen for clarification of their status relative to the officers assigned to their shops. The AFGE then in time-honored manner called on Massachusetts Congressmen and Senators for a non-military investigation of the Armory, charging that the dual military-civilian management of the shops was intrinsically wasteful and that veto of the civilian foremen by their uninformed officer counterparts was dictatorial.[759] The AFGE called for civilian supervision of the Armory, retaining officers only for product inspection. Their campaign for an investigation ran on into 1945. It was espoused by Massachusetts Senator Walsh, but with little result beyond the three-day suspension of the AFGE president for spreading false statements after he equated the authority of "schoolboy" officers over skilled craftsmen with fascism. The war's imminent end suspended the union's campaign for demilitarizing Armory management. About half of the 9,000 men and women in the wartime work force were laid off after V-E Day in the spring of 1945; the AFGE president himself resigned and ran for [Springfield] city

[757] Ibid, pp. 447-50.

[758] Ibid, pp. 580-86.

[759] Ibid, pp. 587-89.

counci1.[760]

The AFGE labor disputes were the last in Armory history, to our knowledge, and appear to have been a side-effect of unusually large and rapid growth of the Armory labor force, military as well as civilian. By the time the AFGE disputes began, virtually all Armory officers were from the reserves, as wartime demands swept up regular Ordnance Department officers for other assignments.[761] Thus the disputes grew from friction between parties with little if any Armory experience. During most periods, management reliance on the skills and experience of workers--critical elements in achieving Armory standards of interchangeability--tended to minimize potential conflict.

G. Labor Skills

Traditional Work Methods

At the beginning of Armory musket production, before the Water Shops were acquired, muskets were hand-made in shops on the Hill without the use of power-driven tools. The work was done by armorers recruited from the New England gunsmithing trade, working in their traditional ways. An experienced armorer could do most tasks required to make a musket. Although division of labor at the Armory apparently began very early, it emerged initially from the wide array of tasks faced by colonial gunsmiths.

Traditional gunsmithing methods persisted in Appalachia until the 1920s, and as recorded are probably the best available indication of the work methods used at the Armory in its early years.[762] The barrel was made from a flat plate of wrought iron called a "skelp." The skelp was heated white hot in a charcoal fire, hammered around a tapered iron rod held by a helper, and the seam hammer welded. A half inch to an inch could be welded before the barrel cooled below welding heat and had to be returned to the fire; fifty or more reheatings were required to finish a musket barrel. The work was arduous and unpleasantly hot.

The welded tube was bored by hand with a "short bit," a twisted steel cutter welded to the end of an

[760] Ibid, pp. 740-44.

[761] Ibid, p. 147.

[762] E.g., John G.W. Dillin, The Kentucky Rifle.

iron rod that served to rotate it and feed it through the barrel, and then reamed with a steel blade set in a hardwood plug to bring it to the .69” caliber of the Springfield musket. It was straightened by hammer blows on its sides to remove kinks revealed by stretching a silk thread through the bore. The outside was rough filed and then draw filed to a tapered shape. The breech end was squared off and then threaded with a hand tap. A breech plug threaded with a die was fitted by adjusting the position of its shoulder relative to the threads so that it would come up snug with the tang at the top of the barrel. (Later, when work at the Armory was being mechanized, this operation proved to be one of the most difficult to accomplish with machinery.) Finally, the barrel was proof tested by firing it with a charge of powder well in excess of the service charge.

The stock was cut from a blank of well-seasoned walnut with tools and methods that would be familiar to a cabinetmaker. Stock-making was a more difficult task than cabinetmaking because all the surfaces of a gun stock are curved. Cutting the stock to give uniform support of the barrel and proper inletting of the lock so as to achieve a good fit between the barrel and the lock are particularly important to proper functioning of the musket.

The bayonet and ramrod were forged from steel, hardened to a spring temper, and polished. Some of the mountings, such as the barrel bands, could be cut out of iron plate, bent to shape, and then welded. The remaining mounting parts and all the lock parts were hot forged to their approximate shapes by hand. This could be done with smith's hammers but it is much easier to use swedges. A swedge consisted of a pair of iron or steel blocks cut so as to form a cavity of the desired shape when placed together. These swedges were probably the only specialized tools required at this stage of development of the production process at Springfield. The forged parts were then filed to final shape; since the forgings were oversize, much hard labor was required in this filing and many files were worn out.

As a set of parts for a lock were brought close to final size, they were assembled and adjusted individually until the mechanism worked smoothly. They were stamped so as to identify them as belonging to a particular lock, disassembled, and the iron parts case hardened. Case hardening involved packing the parts in charred leather in an iron box and holding at red heat for many hours; carbon and nitrogen released by the char diffused into the iron so that, when the parts were

subsequently quenched into water, a hard surface was formed. Steel parts were quenched and tempered. Control of these processes was uncertain and many subsequent failures of lock parts can be traced to faulty heat treatment.

Since the lock parts were individually fitted to one another, the parts of one lock would not work in any other; if a part broke, a new part had to be fitted to that particular lock--the parts were not interchangeable.

Musket-making included much heavy labor, particularly the welding, barrel boring, and filing of the roughly-forged parts of the lock and mountings. Fine work was required in fitting the lock parts to each other and all the parts into the stock. Very few specialized tools were used. The gunsmithing trade was learned through apprenticeship, and required considerable experience to make a musket of good quality. The only methods of quality assurance used were visual inspection and trial of the operation of the finished musket, which relied on the judgment of the inspector rather than measurement.

Early information on the quality of the Springfield Armory muskets indicates serious problems with many muskets made before 1805, and leaves little doubt that recruitment of sufficient numbers of experienced artificers was initially a major problem.[763]

The Transition to Industrial Production

When Eli Whitney undertook to make muskets in quantity for the Federal government in 1798, he immediately recognized that it would be impossible to find enough experienced gunsmiths to staff his armory, the problem already encountered at Springfield. He proposed to convert the handcraft methods of making muskets to industrial production through the use of power-driven machinery and division of labor. Inexperienced workers were to concentrate on making but one part for the musket with the aid of mechanical guides, such as filing jigs. He thought that a task so circumscribed could be quickly learned. In fact, Whitney had great difficulty producing muskets and repeatedly had to

[763] Hodgdon to Ames, September 1, 1796, Letter Book A, copied in Whittlesey, "Extracts;" Whiting to Eustis, January 13, 1810.

ask for extensions of the time allowed him for delivery.[764] The task of replacing the skill of the hand and the eye of the armorer with the precision of machinery was hardly begun in Whitney's lifetime and, as we shall see later, was not completed until well into the 19th century.

The introduction of industrial methods of production is often ascribed to Eli Whitney because of the efforts of some of his biographers, but many other entrepreneurs were also at work on this technology. Unfortunately, the existing written records from the early part of the 19th century reveal little about the production methods used at any of the armories that were making muskets for the government.

Material Evidence: Methods and Results

Examination of artifacts, principally the arms made and the tools used, is one of our best sources of evidence on the methods that were actually used in the production process. Only arms unaltered since manufacture are useful for this kind of study. Inside surfaces of the lock mechanisms are often free of corrosion, and experienced curators of collections can usually detect altered or substitute parts with confidence. The Springfield Armory Museum has an excellent collection of the Springfield arms, study of which is facilitated by the fact that through most of the 19th century the date of manufacture was stamped on each weapon. Careful examination of the surficial markings on parts in lock mechanisms will often reveal the methods used to bring these parts to their final dimensions, and permit evaluation of the quality of the work done in finishing the part. The dimensions of parts from different examples of one model of arm can be measured and compared to one another to determine their uniformity. For some models, comparisons can also be made with the dimensions taken from surviving sets of gages. Author Robert Gordon made a study of the lock mechanisms of ten Springfield rifles and muskets at the Springfield Armory Museum,[765] and the principal results of this work that bear on the manufacturing technology at Springfield are summarized here.

As discussed in Chapter 7, all parts in a lock made in 1803 were finished by hand filing except for a

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[764] Jeanette Mirsky and Allan Nevins, The World of Eli Whitney; K. Hall and Carolyn C. Cooper, Windows on the Works, Industry on the Eli Whitney Site, 1798-1979.

[765] Robert B. Gordon, "Material Evidence of the Manufacturing Methods Used in `Armory Practice;'" "Who Turned the Mechanical Ideal into Mechanical Reality?"

few surfaces that were hollow milled. The screws that attach the lock to the stock were also hand filed, a difficult task since a cylindrical surface of uniform diameter must be made along the length of the screw. There were numerous examples of poor workmanship. A similar distribution of hand work was found in a lock made in 1812, but the quality of the work was distinctly lower than that in the 1803 example. This may reflect the rapid expansion of the workforce that took place at Springfield between 1808 and 1810. Examples of locks studied for the years 1830, 1839, 1844, and 1852 showed little change in the use of machinery in finishing the parts, but there was a steady increase in the quality of the hand work done. The early work could well be described as crude but that done from the 1840s onwards would have to be described as superior by any standard of workmanship. A similar improvement in workmanship was found in lock parts made at the Harpers Ferry, Whitney, and other armories. Lock parts made as late as 1884 still showed evidence of hand finishing to final dimensions, and the quality of this work was extremely high.

The surficial markings on the lock parts examined also showed that a single method of filing lock parts to final dimensions evolved and became accepted by the artificers. Examples of parts from different muskets made in the first decades of the Armory had different patterns of filing, showing that different artificers approached their work in individual ways. By the 1840s, corresponding parts from different locks showed the same pattern of groups of longitudinal and transverse file strokes. Apparently experience had shown the best method of filing a particular part and, once established, this pattern was followed by all the artificers at the Armory.

Changes in the dimensional uniformity of the locks studied parallel the improvements in workmanship. The variation in dimensions between different examples of a given model lock was about 3% in the early years, decreasing rapidly in successive years: by the 1880s, dimensions of lock parts were held to within about a thousandth of an inch, resulting in dimensional variability of less than 0.3%. This is about the lower practical limit of dimensional control that can be attained by artificers comparing parts to gages by the sense of touch. Thus, a ten-fold improvement in dimensional uniformity had been achieved during the 19th century.

The artifactual evidence shows that hand finishing brought lock parts to required dimensional tolerances throughout the 19th century at the Springfield Armory. The poor quality of the work in

the early years confirms Eli Whitney's concerns about the lack of skilled artificers available to carry on small arms making. It also shows that his scheme for avoiding this difficulty through division of labor and the use of power-driven machinery was not realized at least through the first half of the century. Instead of evidence of more use of machinery to finish lock parts, there was instead evidence of steady improvement in the quality of the hand filing of these parts. This may be interpreted as showing the improvement of the mechanical skills of the artificers employed at the Springfield Armory. The first generation of artificers to work at the Armory was learning the skills required to work to close tolerances with the file. Two generations later, in the 1840s, a large number of artificers had acquired these skills and their availability was the principal reason that Springfield and other armories were able to achieve interchangeable manufacture in that decade.

The Evolution of Skills

The continued importance of filing to bring lock parts to gage, and the highly skilled nature of this work, is illustrated by the data in Table 6.5, which shows the percentage of the total labor required to make a tumbler done by different classes of artificers at the Armory in 1864. The "ordinary black-smiths" forged the tumbler blanks, the "ordinary mechanics" milled and drilled the blanks, the "good mechanics" did the finishing, and the "first class mechanics" filed the machined blanks to gage. Of the work done in making a tumbler, filing to gage required the most time and commanded the best rate of pay.

Table 6.5

DISTRIBUTION OF LABOR IN THE MANUFACTURE OF A TUMBLER IN 1864[766]

Type of Artificer Ordinary	Rate of Pay	Percentage of Work Done
	$0.25/ hour	6.3%
Ordinary blacksmith	0.25	39.2
Ordinary mechanic	0.30	2.1
First class mechanic	0.35	52.1

Note: The percentage of work done is percentage of the total labor in making a musket by each grade of labor.

[766] Dyer to Ramsay, February 4, 1864.

The material evidence shows that throughout the 19th century the quality of artificer's work by hand was always superior in uniformity to that attained by the production machinery in the Armory. The artifactual evidence showing the continued reliance on hand work in the 19th century is supported by data on the distribution of artificers between different tasks. Table 6.6 shows the percentages of the total labor in making small arms devoted to bringing metal parts to their required sizes and shapes by hand work (filing) and with machinery (milling, slitting, profiling, boring, rifling, turning, and drilling). The proportion of hand work hardly changed during the first two thirds of the 19th century, but was approximately halved in the last two decades. The proportion of machine work increased slowly up through 1864 and, after this date, became significantly larger than hand work.

Table 6.6

PERCENTAGE OF ARTIFICERS ENGAGED IN HAND AND MACHINE WORK[767]

Year	Hand Work	Machine Work
1811	23%	3%
1820	30	10
1819-25	28	8
1830	27	12
1840	26	10
1850	29	20
1851	25	30
1860	23	26
1864	23	28
1878	12	43
1898	11	45

Notes:

1. Percentages listed are of the total labor by production workers in making small arms at the Springfield Armory.

2. Only work done in bringing metal parts to size after they are forged (or welded) is counted.

[767] Data are from work returns and payrolls except for 1819-25, based on Dalliba and Patterson, and 1851, based on Bessey.

3. The hand work is all filing.
4. Machine work includes milling, slitting, profiling, boring, rifling, turning, and drilling.

Thomas Harvey's 1847 proposal to supply screw machines to the Armory illustrates the character of the work done by machine operators.[768] He proposed to mechanize screw production with:

> 1 heading machine making 40 blanks per minute and operated by one man,
> 3 threading machines making 3.5 to 4 screws per minute each and tended by one man,
> 2 nicking machines (5.5 screws per minute each) and one head turning machine (12 heads per minute) tended by one man, and one occasional machinist to repair, sharpen, and adjust the tools. He estimated the cost of 144,000 screws at $600 instead of the $2,880 these same screws cost the Armory made by existing practice (which was clamp milling and hand threading).

Despite the growth of such machine-production methods, the attainment of final dimensions and of a good working fit between parts was achieved by hand filing rather than precision machining even in the bolt action Krag rifle made at the end of the 19th century. However, the nature of the skills required of artificers in the Armory changed throughout the 19th century as the character of the work was transformed by the introduction of gaging systems and machine tools. In the early years, even with division of labor, an artificer had little guidance on how to carry on his work. He would have to plan out as well as execute his task. He would have to know how to deal with poor tools and irregularities in the metal he was working.

As successive generations of artificers gained experience, making a product that changed very little

[768] Harvey to Ripley, December 10, 1847, RG 156/1382.

in design during the Armory's first seventy years, established methods of working evolved as shown by the file patterns on lock parts described previously. Filing jigs were introduced to serve as guides to the artificer as he filed a part to final dimensions.[769] Files that were more uniformly cut were available, and the iron the artificer worked with was more homogeneous. An artificer could test the progress of his work on each part he made with the gages that were provided for him. Hence, fewer demands were made on the artificer's skills in planning his work and dealing with irregularities in tools and materials. But, he was called upon to work to much closer tolerances, requiring the development of a different set of skills. For example, the use of gages depended on a well-developed sense of touch in judging how well a part actually fitted the gage, in the absence of limit gages until the 20th century (Chapter 3). An artificer had to know where and how much to file off a part to get it to fit in its gage. As long as the Armory depended on hand work to bring parts to their final dimensions, that is, until well into the 20th century, the work of artificers at Springfield remained highly skilled. This conclusion contrasts with the assertions of many 19th century writers who claimed that machinery eliminated skilled hand work.[770]

Machine tools

The introduction of machine tools at the Armory, described in Chapter 7, gradually relieved much of the heavy and hazardous physical labor in small arms making through the first 60 years of the 19th century. Trip hammers for welding barrels (1815) eliminated one of the most arduous tasks in musket making as well as reducing costs and improving the quality of the product.[771] The percentage of labor devoted to welding in making the metal parts of a musket dropped from 29% to 5% between 1811 and 1820 (Table 7.1). In the early years of the Armory, reliance on grinding to shape metal parts was very unhealthful because of the exposure of artificers to dust from the grinding wheels, and injury due to burst grinding wheels was not uncommon. In 1818, the Springfield Armory began to use a barrel turning lathe made by the Springfield Manufacturing Company.[772] As

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[769] E.A. Dixie, "Some old gages and filing jigs."

[770] Ordnance officer George Talcott, who served as Chief of Ordnance from March 1848 to July 1851, was an hopeful advocate of this view, with an eye towards- possible cost savings; see his "Notes on the Springfield Armory," August 6, 1841, reproduced in U.S., Ordnance Department, A Collection of Annual Reports and Other Important Documents Relating to the Ordnance Department.., p. 395.

[771] Lee to Wadsworth, February 6, 1817, RG 156/1351.

[772] Lee to Evans, April 3, 1821, RG 156/1351.

lathes improved and barrels could be brought closer to final dimensions by turning, less metal had to be removed by grinding. Between 1811 and 1820, grinding decreased from 14% to 6% of the total metal work in making a musket (Table 7.1). In 1840, Thomas Warner's invention of a milling machine that would shape bayonets without grinding removed one of the most hazardous jobs from the Armory.[773] Because of the introduction of better metal cutting machines, the consumption of grindstones per musket made dropped from 14.9 pounds in 1823 to 2.3 pounds in 1852 and the percentage of artificers engaged in grinding dropped fivefold.[774]

The physical labor in making lock parts was reduced first by improved forging technology, which allowed forged blanks to be made closer to their final size, and later, by milling machines that could do roughing cuts on the forged blanks. By 1852, 57 milling machines served by 26 artificers machined lock parts that were subsequently finished to gage by 24 filers.[775] In 1823 one file was worn out for each musket made at Springfield;[776] by 1852 this had been reduced to one file for every three muskets. The introduction of milling machinery before 1864 reduced the amount of physical work that an artificer had to do to bring a forged tumbler blank to size to a tenth of that required to do the same job with files alone.[777]

The appearance of machine tools allowed the lock filers to concentrate their efforts on the final, precise shaping of parts that could not be accomplished by machinery. Work of brawn was replaced by work of precision. At the same time, tasks requiring new skills were created in the Armory: machine manufacture prior to commercially available machine tools; manufacture and frequent resharpening of milling machine cutters; and making fixtures to hold work in machines, among others. These tasks were done by a class of workers at the Armory known as "jobbers." The new machine tools required new skills to operate, even though they were often described by

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[773] Talcott, August 6, 1841.

[774] Bessey; Abbott; Dalliba; Patterson.

[775] Bessey; Abbott.

[776] Springfield Armory, "Estimated Amount & Weight of Stock & Material Necessary to Make 12,000 Muskets," April 1823. SANHS.

[777] Gordon, "Who Turned..:" "Material Evidence.."

contemporary writers as "self-acting." We have little direct evidence on these skills but inspection of surviving machines suggests that they could not be entrusted to unskilled boys, as was sometimes claimed by 19th century reporters. However, the wage rates listed in Table 6.5 suggest that machining did not require the level of skill demanded of filers. The age and experience of 19th century machine operators will require additional research to resolve questions of skill in small arms making.

Specialization

Counting the number of men who worked at more than one kind of task (filing and milling, for example) during a month gives some indication of the degree to which the work of artificers was specialized to a particular task. The results, listed in Table 6.7, show no evidence of a trend toward more specialization through the 19th century. Instead, it appears that the artificers at the Armory were able to shift between different kinds of work whenever there was a need to do so, which would be most likely when the workforce was small (1878) or a new model arm was coming into production (1840, 1843). The large workforce and the need to achieve maximum production with established methods seems to have led to less shifting about between different types of work in 1864, and to a much finer division of labor than at any other time in the 19th century.

Table 6.7

PERCENTAGE OF ARTIFICERS DOING MORE THAN ONE KIND OF WORK IN A MONTH[778]

Year	Percentage
1811	11
1820	5
1830	17
1840	22
1843	48
1850	9
1860	33

[778] Based on work returns and payroll records of the Springfield Armory.

1864	18
1878	38
1898	36

Note: Artificers who did the same kind of work but on different parts not included in this count.

The adoption of the bolt-action repeating rifle in 1892, with its more complicated mechanism, greatly increased the number of individual manufacturing operations. In 1898, 84% of the artificers engaged in metal work were doing more than one operation, such as several successive millings, and 36%, more than one kind of work (such as milling and profiling). Some men worked on as many as 10 different operations within the month sampled.

Metallurgical Skills

The preceding discussion has concerned the skills used in shaping and cutting metal parts so as to make them sufficiently uniform to be interchangeable. When the concept of interchangeability was being introduced, many believed that differences in dimensions caused by hardening would make it impossible to attain a useful degree of uniformity.[779] Properly shaped parts can be easily ruined by faulty heat treatment procedures during case hardening (of iron parts) or quenching and tempering (of steel parts). Hence, metallurgical skills were also required of the artificers at Springfield.

Welding, annealing, or heat treating operations were performed on almost every metal part in a musket. As long as barrels were made from skelps, welding was a critical skill at the Armory. In 1825 welding alone accounted for 33% of the labor cost of making a barre1.[780] Hammer welding of barrels continued until rolls for welding were brought over from England in 1859, when an English welder transferred the special experience needed to operate the rolls.[781] The need for barrel welding was finally eliminated in 1873, when wrought iron barrels were replaced by steel.

[779] "Testimony..," p. 56.

[780] Lee to Bomford, August 1, 1825, RG 156/1351.

[781] Robert B. Gordon, "English iron for American arms: Laboratory evidence on the source of iron use at the Springfield Armory in 1860."

All lock parts required heat treatment. Wrought iron parts were case hardened and steel parts tempered to the necessary hardness. The bayonet and ramrod, which were made of steel, also had to be hardened. The lists of artificers at the Armory in 1825 and 1852 do not identify heat treating other than annealing as a recognized specialty. In 1864, heat treating was done by "day labor," which apparently commanded lower wages than did the artificers,[782] implying that relatively unskilled workers did the heat treating. Both the artifactual and documentary evidence now available is limited, but what we have indicates that heat treating was often badly done at the Armory. The 1828 inspection report on 100 Springfield muskets made in 1819 and 1820, for example, states that the lock plates on about half of the muskets were too soft.[783] The employment of relatively unskilled labor for heat treating, which throughout the 19th century required superior judgment and experience since no instruments to control the process were available, may be one reason for the poor quality of work done. It was only in 1918 that the Armory obtained the services of a professional metallurgist to resolve problems that were arising with heat treatment of rifle parts.[784]

Labor force

The difficulties encountered at the Springfield and Whitney armories in producing muskets of satisfactory quality, as documented by the artifactual as well as documentary evidence, shows that the supply of artificers with the skills needed for manufacturing was unequal to the demands of the armories in the early years of the 19th century. The deterioration in quality of muskets made at Springfield in 1812 compared to those made a decade earlier suggests that there was not yet a pool of industrially talented labor to draw upon in times of emergency. The situation was entirely different in 1861. The Armory was able to expand its workforce and greatly increase production with, apparently, little decrease in product quality. This shows that the manufacturing skills first developed at the armories had spread to other industries and that workers in these other industries could shift to armory work when required. By 1860, armory work had changed from unusual to commonplace in the industrial establishment of the United States.

[782] Dyer to Ramsay, February 6, 1864.

[783] R.L. Baker, "Report of an Inspection of 100 Springfield Muskets 1828," SANHS.

[784] Julian S. Hatcher, "Metallurgical improvements in the Springfield rifle."

ABBREVIATIONS IN NOTES

ARCO	U.S., Ordnance Department, Annual Report of the Chief of Ordnance to the Secretary of War for the Fiscal Year Ended June 30, ----.
ARSA	Annual Report of Operations at the Springfield Armory. Titles vary, and reports appear in different archival sources, as noted.
RG 156/	Record Group 156, Records of the Office of the Chief of Ordnance, National Archives. Record entry number follows slash.
SAHS	Springfield Armory Historical Summary for the Period ----, on file at Springfield Armory National Historic Site. These are semi-annual or annual reports covering the years 1951-1965.
SANHS	Springfield Armory National Historic Site. This refers to material held by the National Park Service at Springfield.

Chapter 7

MECHANIZATION

A. Introduction and Sources of Information.

One organizational and two technical developments were critical in the enormous increase in production accompanying industrialization in the late 18th and the 19th centuries: production shifted from artisans' shops to centrally-organized factories; water and steam power was applied to most of the physical work of manufacturing; and iron was substituted for wood in the construction of both the machinery of production and many of the goods made.[785] All of these elements were clearly present at Springfield Armory, credited by Alfred Chandler as the place where the modern factory system of the United States originated.[786] According to Chandler, skilled mechanics trained at Springfield devised new machine tools to produce products including agricultural implements, sewing machines, locks, scales, and typewriters. Other historians of technology describe the Armory as a major force in bringing about the production of manufactured goods with machine-made, interchangeable parts.[787] Mechanization is, therefore, a major issue in any history of the Armory.

The documentary record of mechanization at the Armory in the 19th century is sparse, and the only surviving machine from the first five decades of the Armory is the Blanchard stock turning lathe now in the Armory Museum. Reports by both official and unofficial visitors lack technical detail and are usually not explicit about numbers and uses of machines. Inventories of the tools and equipment of the Armory, which have been found for a few years between 1834 and 1844, list and assign values to, but do not describe, the machinery in place each year. Armory annual reports, which commence regularly in 1845, list new machinery built and bought, but not machines removed from service. Recently, a set of drawings by James Burton of machinery probably used at the Harpers Ferry Armory was discovered. (These drawings are now at the Harpers Ferry National Historical Park.) They are undated but appear to be for the period 1849-1854, when Burton was acting Master Armorer at Harpers Ferry, and are probably representative of the machinery used

[785] Nathan Rosenberg and L.E. Birdsell, How the West Grew Rich.

[786] Alfred D. Chandler, Jr., The Visible Hand: The Managerial Revolution in American Business, pp. 72-5.

[787] For example, David A. Hounshell, From the American System to Mass Production, 1800 to 1932, p. 3.

throughout the arms industry at that time.

The best evidence we have of the effects of mechanization on the Armory work process comes from the data in the work returns and payroll records.[788] Until 1818 these documents cover only the Water Shops and so give an incomplete record of the work done. Thereafter, they list the work done by each employee. We sampled this data for the month of January in representative years, counting the number of men doing each task. When a man worked at more than one task, only the first name has been counted. This could result in some secondary tasks being undercounted, but we believe that this is not a significant problem. Table 7.1 summarizes the distribution of labor among the different tasks in making small arms at Springfield, derived from this data. Only direct production labor is included in this table. Tasks in making and repairing machines and on the buildings and grounds are not included, nor are work of supervisors and foremen.

We found no record of the employment of artificers working at the Hill Shops in 1811. The percentages in Table 7.1 will be too large for the work done only at the Water Shops because of the omission of work, principally stocking, done on the Hill. We believe that, were the work done on the Hill included, the distribution of work among the tasks included in the table would not be significantly altered except for stocking.

Table 7.1.

Distribution of Tasks in Making Small Arms at Springfield Armory

Task	1811	1820	1830	1840	1843	1850	1860	1864	1878	1898
Roll	-	[1]	1	4	1	1	*	*	1	1
Forge & draw	[18]	20	20	16	12	18	13	5	2	5
Weld	[29]	4	8	7	5	5	2	4	2	0
Mill & slit	[3]	3	3	4	9	7	12	14	20	20
File	[23]	30	27	26	15	29#	23	23	12	11
Grind	[14]	5	4	3	2	5	2	1	3	1

788 Springfield Armory Work Returns, RG 156/1371, and Payroll Records, RG 156/1379.

Profile	0	0	0	0	0	0	0	1	5	11
Bore	[5]	4	4	2	4	5	5	8	7	0
Rifle	[0]	0	0	0	0	0	1	1	1	<1
Turn	*	2	3	2	4	4	2	1	3	2
Drill	*	1	2	2	9	4	6	3	7	11
Straighten	*	<1	*	*	*	*	*	1	1	2
Heat treat	*	5	1	1	2	2	3	3	5	2
Polish & buff	[8]	5	4	5	5	7	6	5	4	5
Blue & pickle	*	*	<1	*	*	*	*	*	3	1
Assemble	*	*	*	*	4	1	2	1	1	3
Stocking	*	13	13	10	9	6	7	9	10	9
Inspect-	*	*	<1	7	3	2	*	5	8	7
Miscellaneous	[0]	6	7	11	16	4	16	15	5	8

Notes below to **Table 7.1**:

This table shows the percentages of direct labor in making a musket or rifle devoted to each class of work listed. Data are from the payroll and work returns and were sampled for the month of January for each year listed.

* = *no data*

[] = *Data are for the Water Shops only*.

= *58 men filing hammers (for conversions) not counted*.

"Miscellaneous" = *all tasks not enumerated above*.

<1= *a numerical value less than 1*.

Note that the Master Armorer, Assistant Master Armorers, and foremen are not counted.

B

B. Hand Tools

Table 6.6 showed the dominance of hand over machine work at Springfield Armory through the first half of the 19th century. The character of the hand work can be inferred from the tools used. The earliest inventory showing all of the tools at the Armory is for the year 1835, from which the principal hand tools are presented in Table 7.2 below. At this time, smithing accounted for about 25% of the total labor force making muskets; filing, about 30%; stocking, about 13%; and, metal

machining, about 10%.

The blacksmiths blanked out all of the metal parts (except the barrels) with sledges, swedges, and headers as they worked at anvils. The cold chisels would have been used for the first rough trimming of the forge work. Most of the final shaping of the metal parts, mostly held in filing gigs, was done with files. Files and filing jigs are the most abundant hand tool listed for metalworking. All threads were cut by hand using the taps, screw dies, screw plates, and screw stocks. The hand work on the stocks was done with chisels, gouges, and planes; holes were bored with braces and bits.

Although some specialized tools, such as jigs and gages, were in use in 1835, the cutting of wood and metal was largely done with familiar, standard artificers' tools: chisels, gouges, and files. These were the same tools used from the earliest days of the Armory for such work. They persist as major items in Armory inventories throughout the 19th century.

Table 7.2.

PRINCIPAL HAND TOOLS USED AT THE SPRINGFIELD ARMORY IN 1835[789]

Smith's Tools:	279 Tongs	85 Heading tools
	62 Anvils	74 Swedge sets with jumpers
	59 Sledges	
Metalworking tools:	2334 Files	115 Filing jigs to guide hand work
	382 Hand hammers	66 Pliers
	238 Taps	55 Screw dies
	220 Cold chisels	38 Trim & punch dies
	208 Stamps	31 Screw plates
	154 Screw drivers	14 Die stocks
	136 Wrenches	
Woodworking tools:	257 Stocker's chisels	89 Planes
	186 Stocker's gouges	83 Bits
	100 Braces	19 Stocker's saws

Tools, such as drills, that might be used in either hand or powered equipment are not listed here.

[789] Inventory of Ordnance and Ordnance Stores on hand at Springfield Armory in charge of the Master Armorer, Dec. 31, 1835, SANHS.

C. Definition and Origins of Mechanization

Types of Mechanization

Historians of technology have used the term "mechanization" in a variety of ways: the application of power-driven machinery to manufacturing operations. Three distinct types of mechanization of production can be recognized in the historical record.

In the first, and simplest, type of mechanization, tasks formerly done by hand are done with power-driven machinery without any essential change in the nature of the work processes used. Examples are forging and welding with a trip hammer, grinding on a power-driven grindstone, and polishing with mechanically rotated discs. The physical labor involved in each task is reduced and the work may be speeded up, but the artificer performing the task continues to control it in much the same way as would be done in hand methods.

The second level of mechanization involves carrying out tasks with machines that could be done only with great difficulty by hand but with full control of the machine still exercised by the artificer. For example, a skilled artificer may be able to file a good approximation to a cylindrical surface on a piece of iron, but no matter how skillfully the work is done, it cannot duplicate the regularity of a cylinder turned on a lathe.[790] The second level of mechanization introduces new skills, such as grinding and setting the cutting tools on a lathe, that may be quite different from those used in hand work. At this level of mechanization, unlike the third type, every aspect of the operation of the machine is controlled by the artificer. On a lathe or miller, for example, the feed of the cutting tool into the work is by hand.

The third type of mechanization involves combining three elements in one machine, power drive of the cutter, power feed of the workpiece into the cutter, and fixtures to accurately and rapidly position each workpiece as it is inserted into the machine. In a file-cutting machine, for example, the blank to be cut is advanced by the spacing of one file tooth between each stroke of the machine. If automatic stops are provided to disengage the feed when the requisite work has been completed, the

[790] The lathe might be powered by the artificer while the work is carried on if the task is light enough. There are not many such tacks in making small arms and the use of hand-driven machines falls outside of the definition of mechanization we have adopted.

machine becomes "self-acting"; it can be set in motion and left unattended until it is time to insert a new piece of work (that is, if nothing goes wrong). At a further level of development, self-acting guides for the cutting tool may be provided so that complex shapes can be cut, as in the Blanchard gunstock lathe, and the guidance of the cutter may be by electronic rather than mechanical devices. In principle, the only skills required to operate such a machine are those involved in putting in and taking out the work. Once the difficult task of setting up the machine is completed, relatively inexperienced persons are expected to be able to operate it. In fact, we will see that new skills, such as judging when cutters need to be resharpened and dealing with inconsistencies in the stock used, are required.

The effects of mechanization on the character of the labor process are of three kinds. The first is the reduction in the actual physical work required of an artificer to complete a given task. Use of a trip hammer greatly lightens the labor of welding a barrel, although it may increase the risk of injury resulting from mistakes in the manipulation of the work and subject the artificer to demands for increased output. The second is the creation of a need for new skills, such as knowing how to sharpen cutters and adjust the speed and feed of a machine tool to produce work of good quality. These skills are not simply transferred from experience gained with hand tools but must be learned through work on machinery. The third effect arises from making machines self-acting. So long as the progress of the machine is not disturbed by wear of the cutters or inconsistencies of the material being worked, and the fixtures for locating and holding the work are well designed, running the machine is reduced to shifting the work in and out of it, usually a relatively simple task This substitution of a materials handling task for the actual cutting of metal by an artificer is now described as "deskilling" by some writers. However, the fact that a machine has been made self-acting does not automatically mean that its operations have been deskilled. Throughout the 19th century, the limitations of carbon-steel cutters, bushed bearings, and wrought iron conspired to make the operation of machine tools a challenge even on routine work. All of the above effects on the artificers' work affected production at the Springfield Armory as mechanization advanced but, as we have seen in Chapter 6, there was more development of new skills than of deskilling in the mechanization of small arms making until well into the 20th century. It is a major oversimplification to interpret this stage of mechanization as simply a device for establishing management control over labor.

In the very first years of the Springfield Armory, all the work of making muskets had to be done by hand because there was no source of power at the Armory site. As we have seen in Chapter 4, a water power site was acquired and mechanization of small arms making commenced during the Armory's first two years. The earliest machinery accomplished mechanization of the first type by applying power to run hammers and grindstones. Within fifteen years, mechanization of the second type was being developed for some metalworking operations, such as barrel turning and making screws. At least another fifteen years elapsed until machines with power feed—the third stage—were applied to metalworking. The sequence on woodworking was quite different. The first and second types of mechanization were passed over and the first machines used, such as Blanchard's series of stocking machines, were of the third type. The reasons for this difference are to be found in the technical differences of cutting wood and metal.

Origins of Mechanization

After limited beginnings in the 16th century, interest in mechanization for small-arms production gathered momentum in the early 18th century. A machine for milling rifle barrels was included in the collection of machinery approved by the French Academy in 1716. It used a circular cutter with file-like teeth and appears to have been intended for shaping the outside of barrels.[791] This machine was probably more important in illustrating a concept than in actually cutting metal; in the description of Honoré Blanc's late 18th century system of manufacture of muskets with interchangeable parts there is no mention of power-driven machinery.[792]

When the necessity of producing muskets quickly and in quantity arose late in the 18th century in the United States, New England entrepreneurs had no body of experienced artificers to draw on. They did have easy access to abundant water power sources that could be developed at low cost.[793] Eli Whitney and others believed that these power resources could be used to drive machinery that, when combined with division of labor and the use of filing jigs to guide artificers' hand work, would

[791] C. Fremont, Files and Filing, cites Villons, "Recoil des Machines de 11Academie," p. 71.

[792] William F. Durfee, "The First Systematic Attempt at Interchangeability in Firearms."

[793] Robert B. Gordon, "Hydrological Science and the Development of Waterpower for Manufacturing."

allow production to proceed rapidly in the hands of inexperienced staff.[794] Edwin Battison has shown, with the aid of artifactual evidence, that only a little was accomplished toward this goal in Whitney's lifetime and that the so-called Whitney milling machine, which has power feed and automatic stops, was acquired by the Whitney's armory some years after his death, although it remains the oldest surviving example of a power-driven milling machine. Battison found that the only machine tool work done on the parts of locks made at the Whitney Armory before 1825 was hollow milling of the tumbler.[795]

Eli Whitney is the best known of the early advocates of mechanized manufacture but, within a few years of the founding of the Whitney Armory, other private arms makers in New England were developing manufacturing techniques using power-driven machinery. Two important examples are Asa Waters and Simeon North. Asa Waters first applied the trip hammer to the arduous task of welding barrels and it was at his armory in Millbury, Massachusetts, that Thomas Blanchard built a lathe that could not only turn the tapered section of the welded barrel but also form the flats at the breech end. Simeon North had a milling machine in operation before 1817 that could cut flat surfaces on metal lock parts.[796]

Despite the early interest in manufacturing with machine tools in the United States, the paradigm of mechanized production was developed in England, in the form of the mill for making blocks at the Portsmouth dockyard of the Royal Navy. A sequence of machines, some of them self-acting, was arranged in the mill so that there was a steady flow of work from one machine to the next. The machines could be adjusted to make blocks of different sizes. Since the shape of the outside of a pulley block is quite a complex curve and difficult to make by hand, and the machines successfully performed most of the shaping required to make a block, substantial savings in labor costs were attained. These machines were described in many publications and were known to American mechanics by the second decade of the 19th century.[797]

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[794] E.g., Whitney to Walcott, May 1, 1798, Whitney Papers.

[795] Edwin A. Battison, "Eli Whitney and the milling machine." Study of additional artifacts shows that hollow milling was also used on the sear; see Robert B. Gordon, "Material Evidence of the Manufacturing Methods Used in `Armory Practice.'"

[796] Charles W. Fitch, "Report on the Manufactures of Interchangeable Mechanisms."

[797] Carolyn C. Cooper, "The Production Line at Portsmouth Block Mill," and "The Portsmouth System of Manufacture."

The Portsmouth pulley-block machinery remained in use until well into the 20th century but this installation in England, although frequently visited by the public and widely described in the press, was not emulated by other British industries. The next known production line operating with self-acting machinery was the one set up by Thomas Blanchard at the Springfield Armory in the 1820s. This set of machines, which completed half of the manufacture of a gun stock (the other half of the work was reserved for traditional hand work at that time), is described later in this chapter and is the principal antecedent of the mechanized production lines in American factories. The next was at Hall's rifle works attached to the Harpers Ferry Armory.

Both the Portsmouth and the Blanchard production machinery worked on wood. One of the reasons that the machinery was successful was that wood could be cut rapidly and precisely and with small applied force with carbon steel cutting tools operating at high speed. The necessary spindle speeds could be attained with belts and pulleys and machines of sufficient rigidity could be made with the technology available in the early 19th century. Transfer of this technology to metal working proved to be difficult. Higher forces are needed to cut metal than wood and, to achieve either high accuracy or a significant production rate, metal-working machinery required more rigid construction than could be attained with the materials and bearings available in the first decades of the 19th century. Considerable experience was needed with lathes and other machines with hand feeds before self-acting metal cutting machines could be designed. Additionally, the wrought iron available for the manufacture of metal mechanisms was not sufficiently homogeneous to allow a self-acting machine to run for very long without attention. The degree of success attained with metal working is described later in this chapter.

D. Mechanization of Springfield Armory Stock-making, c1823-1854

At Springfield Armory, the mechanization of gunstock manufacture in the 19th century took place over two generations. Inside contractor Thomas Blanchard constructed and installed machines of the first generation in the 1820s, which were replaced in the 1840s and early 1850s by second-generation machines designed primarily by Master Machinist Cyrus Buckland. Historians of technology consider Blanchard's first-generation stocking machinery highly important, both as

individually ingenious machines that performed tasks previously done only with hand tools, and as comprising collectively the first known production line of sequential special-purpose machines in an American manufacturing industry. Such historians regard Blanchard's machinery as a technological paradigm for the whole "American system of manufactures," the forerunner of 20th-century mass production.[798] Cyrus Buckland's second-generation gunstocking machinery, which was more nearly complete than Blanchard's, was also an object of wonder and praise in its time.[799] Foreign governments bought sets of Buckland's machines from private machine-tool makers for use in their armories.[800]

Despite the impressive reputation of Blanchard's and Buckland's gunstocking machinery both in the 19th century and today, a close look at what gunstocking involved as a hand process, and then at what the stocking machines actually did, shows that both contemporary and retrospective reports about them have overstated what their machines could do. In fact, they left a great deal to be done with hand-tools.[801] But only in the twentieth century was the stocking process significantly mechanized further.

Before mechanization of gunstock manufacture began in the 1820s, the tasks of a gunstocker at Springfield Armory were already different from those of a handicraft gunsmith. As explained in Chapter 6, division of labor had started taking place at the Armory some years earlier, so the stocker's job was specialized to woodworking, and came after others in the production sequence for a musket. Before a musket reached a stocker, the forgers and the filers and the barrel welders and the machinists had already made the metal parts and drilled screw holes in them and made the screws for fastening them onto a wooden stock. The stocker had to shape the stock and fit all the metal parts

—barrel, lock, trigger and guard, and the various "mountings"--onto it. Starting with a blank of

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[798] E. g., David Hounshell, From the American System to Mass Production, p. 35, 38.

[799] For effusive praise, see Bessey's Springfield Directory for 1851-52, p. 163.

[800] Fitch, p. 631; for stocking machines ordered by the British, see Nathan Rosenberg, ed., The American System of Manufactures, pp. 181, 191.

[801] For a more detailed exposition, see Carolyn C. Cooper, "A Whole Battalion of Stockers: Thomas Blanchard's Production Line and Hand Labor at Springfield Armory."

black walnut wood sawn roughly to an outline shape of a gunstock, he cut or "let in" sunken places, or "beds," into the stock, having the proper shapes and depths for receiving the metal parts; drilled screw holes; and fastened the parts into their beds. The stocker also had to shape the exterior of the gunstock so that it would have smoothly rounded contours instead of sharp corners. Then he would smooth and polish and oil the surface of the gunstock.

By the method of "cut and try," the pre-mechanized gunstocker accomplished this job with various hand tools: drills, gouges, chisels, and stockshaves (similar to spokeshaves), standing at a bench equipped with a vise to hold the stock steady while he worked on it. A good stocker could complete about three guns every two days. In 1819 there were about 35 gunstockers at the Armory out of a total production work force of 231.[802] They worked, along with the lock filers and finishers, in the largest Hill shop building, and were paid at a piece rate of $1.06, $1.12, or $1.16 per gun.[803]

In 1819 Thomas Blanchard, a mechanic in Millbury, Mass., made and patented an irregular turning lathe capable of shaping a gunstock all in one operation, and shortly afterward developed a machine by which to hollow out the bed for a lock. Alert to such mechanical improvements, Roswell Lee paid Blanchard to build a gunstock lathe at Springfield, and later gave him a contract to take aver the job of "half-stocking" muskets at Springfield Armory for 37 cents each (afterward lowered to 32 cents). Blanchard stayed at Springfield Armory for several years from mid-1823, developing a series of 14 special-purpose gunstocking machines, which he hired his own workers to run. After obtaining agreement from the U.S. government to pay him a 9-cent royalty fee on every musket to be stocked until 1834, Blanchard left the Armory in possession of his 14 machines.[804]

Unfortunately, the only direct information available about Blanchard's "first generation" stocking machines is an 1827 list of their names, shown in Table 7.3, plus the irregular turning lathe that survives at the Springfield Armory Museum and whose patent specification has been preserved by the Patent Office. It was a completely "self-acting" machine, requiring no intervention by the operator between loading and unloading the workpiece. By bringing a rapidly rotating and slowly

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[802] Springfield Armory stockers' work return, 1819, RG 156/1371; Deyrup, Table 4, p. 245.

[803] Dalliba, p. 542, Springfield Armory payroll, 1819, RG 156/1379.

[804] Contract between Thomas Blanchard and George Bomford, Feb. 7, 1828, RG 156/1382.

traversing 18"-diameter cutter wheel against a piece of slowly rotating wood and controlling the cutter's in-and-out motions by the pressure of a friction wheel on a parallel rotating model stock, it copied the undulations of the model in three dimensions, as a key-copying machine copies the edge of a key in one dimension. The general characteristics of the other thirteen machines can be inferred from the characteristics of their second-generation successors, about which much more is known. By such inference, we can discern that the thirteen fall into four other types besides the irregular turning lathe itself. Same--(1), (2), and (8) in Table 7.3--are saws; same--(7) and (14)--are drills; one--(11)--is a variant form of Blanchard lathe with wide, non-traversing rotary cutters and hand-controlled rotation of the workpiece; and the others--(4), (5), (6), (9), (10), (12), and (13)--are vertical-spindle inletting machines. These had small cutters like drill- or router-bits to excavate cavities of irregular shape and depth by copying the motions of an attached parallel "dummy" spindle as it traced the interior of an appropriately shaped metal pattern.

The half-stocking machines ran on water power at the Lower Water Shops, a mile distant from Armory Hill, and were operated by six or seven men. With these machines they shaped the exterior of the gunstock, both front and rear; cut beds for the barrel, the barrel bands, the lock, and the butt plate; and bored the necessary screw holes for fastening these various parts to the stock. Once all of Blanchard's machines were running satisfactorily, the stockers at the Hill Shops continued to perform only the "other half" of the job, using hand-tools to do so. They cut beds for the trigger, trigger plate and trigger guard, the ram rod, and the band springs; smoothed and oiled the stock; and fastened all the parts together so that they worked smoothly. For this they were paid 50 cents per stock.

Hence the total price to the Armory for machine and hand work on the stocks was 87 or 82 cents during Blanchard's contract. After he left, the Armory stopped paying him 32 cents but commenced paying the machine operators, at piece rates. In 1835 the piece rates paid for seven machine operations ranged from \$.0125 each for fitting on butt plates to \$.0525 for fitting in barrels, and the rates for hand and machine work per stock totaled \$.69.[805] The piece rates for stocking rose sharply in 1836, so that in 1837 they actually totaled \$.90 per stock completed, a little higher than they had

[805] Springfield Armory work returns for stockers and lower water shop, Jan. and May 1835. Blanchard's royalty had ceased in 1834.

been before Blanchard began his half-stocking contract in 1823.[806] New machines designed by Cyrus Buckland began to replace Blanchard's machines in 1840-41.

Buckland's machines benefited from the improvements in the quality and quantity of iron and steel available for machine-building since Blanchard's day, and the improved metal-working hand- and machine-tools for this purpose. His gunstocking machines had sturdy iron frames instead of the massive wooden frames that the preceding generation probably had, to judge by the only surviving Blanchard original—the butt-turning lathe at the Springfield Armory Museum. By comparison, the Buckland-type machines that were made in the mid-1850s by Ames Manufacturing Co. and sent to the Enfield Armoury in England are quite elegant in appearance.[807]

Buckland added machines for both "halves" of the gunstocking procedure, and redesigned the original machines, including the irregular turning lathe and the machines for bedding lock, barrel, buttplate, and bands, on Blanchard's general principles. Some of Buckland's machines performed the operations of more than one Blanchard machine and vice versa. Buckland's machines, listed in Table 7.3, also included new ones to bed the trigger and trigger guard (#[13] in the list) and to bed the band springs and make the part of the ramrod channel that was an open groove (#[14]). These had formerly been in the non-machine "half" of gunstocking. Boring the hole for the closed portion of the ramrod channel remained a hand-tool operation until around 1860 when someone succeeded in using a machine for that task, which reduced it to "one-fifth of the former labor" it had taken.[808]

Buckland's mechanization of previously hand-tool tasks precipitated a new division of labor among the hand stockers at the Hill shops as well as the stocking machine operators at the Lower Water Shops. From 1841 the hand-work formerly known simply as "stocking" at $.50 apiece was subdivided into such job descriptions as "shaping" stocks at $.25, "sandpapering" them at $.125, and

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[806] Springfield Armory work returns for stockers and lower water shop, Jan. 1837.

[807] Some are depicted in The Engineer, a six-part article on "The Royal Small-Arms Factory, Enfield." These engravings are reproduced in Cooper, "A Whole Battalion.." Buckland-design machines for lock-bedding and stock-turning survive at the Science Museum in London and the American Precision Museum in Windsor, Vermont, where there is also a later barrel-bedding machine of the type.

[808] Fitch, p. 634.

"fitting in band springs" at $.057.[809] This rearrangement of gunstocking machines and hand labor was part of the general retooling of the Armory for the production of percussion instead of flintlock muskets, initiated under Master Armorer Thomas Warner in the late 1830s and carried through by Cyrus Buckland, who became Chief Machinist in 1842. Over the following decade the rest of Buckland's second-generation stocking machines were intermittently installed at the Armory, while in 1845 and 1846 the machines and stockers were all integrated for the first time in a steam-powered stocking shop on Armory Hill.[810]

The new machines and division of labor gradually lowered the time and cost of the gunstocking process. At the end of 1843 the total process was taking more than three and a half hours per stock and the piece rates for hand-tool and machine operations cost a total of $.607 per stock.[811] This represented a significant saving over the pre-1820 rate of more than a dollar and over the rates in 1835 and 1837 of $.69 and $.90. But by mid-1854 the piece rate total had dropped much further to $.42 and the labor time per stock had declined to a little less than one and a half hours.[812] This represented a big increase in stocking productivity since the pre-Blanchard era, when a stocker took one and a half days per stock. As Table 7.3 shows, the machine labor constituted a total of about 29 minutes, or less than a third of the stocking time in 1854, leaving two-thirds to hand labor.

E. Mechanization of Armory Metalworking to the Civil War

Mechanization of Armory metalworking began with the establishment of the Lower Water Shops, which before 1800 was equipped with trip hammers, two lathes (probably used for turning breech plugs) and, possibly, power-driven grindstones and polishing discs.[813] During research for this report, examination of a musket made at the Armory in 1803 also showed that the tumbler was hollow milled, but that the side screws were shaped by hand filing. The hollow milling was a

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[809] Springfield Armory work return for stockers, Jan. 1841.

[810] U.S., Congress, House, Superintendents of National Armories..., Appendix B, pp. 155-59; ARSA 1847, RG 156/1354.

[811] Springfield Armory work return for stockers and lower watershop, Jan. 1843.

[812] Rosenberg, pp. 137-42.

[813] Felicia J. Deyrup, Arms Makers of the Connecticut Valley, p. 35.

technique probably done with a power-driven machine;[814] if so, this would have been the first machine tool for shaping lock parts acquired by the Armory.

Whiting reported that by 1810 water power was used for cutting and slitting screws; for milling tumblers, side screws, and trigger plates; and some of the barrel boring.[815] Hammering and boring with power equipment were established technologies in America at this time. A water-powered hammer was part of the equipment at the 17th-century Saugus iron works, and cannon were bored at Salisbury during the Revolutionary War.[816] Hollow milling with power was probably new technology in gun making in the first decade of the 19th century, but study of artifacts will be needed to decide if hollow milling was used first at Springfield, Whitneyville, or elsewhere. We believe that, in all of the machine work done in 1810, the function of the applied power was only to drive the cutting (or hammering) tool, and that the machines had neither power feed nor were they self-acting. This equipment represents the first stage of mechanization of small arms making, as described at the beginning of this chapter.

Making a Musket In 1810

The following account is based on the report on the Armory by Whiting,[817] except as otherwise noted, and provides a baseline of comparison for later Armory mechanization. In 1810, 204 armorers working under the supervision of a Master Armorer and his assistants made 10,302 muskets. Thus, about six man-days were required to complete one musket. There were at least twenty different production occupations established by this date.[818] The principal metalworking tools they used were the hand sledge and swedge for forging parts and welding barrels, and files for shaping parts; files wore out at the rate of one per musket. Holes were punched rather than drilled for the most part, and we infer that taps and dies were supplied for threading screws and the breech

[814] Battison.

[815] Whiting to Eustis, January 13, 1810, Records of the Office of the Secretary of War. This account is not fully substantiated by artifactual evidence; we found hand-made side screws in an 1812 Springfield musket at the Armory Museum.

[816] E.N. Hartley, Ironworks on the Saugus; Louis F. Middlebrook, Salisbury Connecticut Iron.

[817] Whiting to Eustis, January 13, 1810.

[818] Deyrup, p. 240.

plug. Stocks were made with chisels, gouges, and sandpaper. Power-driven machinery was used for forming the barrel skelps and boring the barrels, grinding, and probably, polishing the surfaces of iron parts, turning the breech plug and milling the tumbler. No measuring equipment, no gages, and no filing jigs appear to have been used, but pattern parts must have been supplied to the armorers for reference.

Barrel skelps purchased from ironmasters in the Salisbury District were cut to length and formed into tubes around a mandrel with a trip hammer at the Lower Water Shop. They were then welded by hand by a barrel welder and two assistants; a welder was able to produce 4 to 5 barrels per day in what must have been hot and arduous work.[819] The welded barrel was bored and reamed by power, finished and straightened by hand, the outside ground to shape (on a power grindstone) and then polished (probably with power-driven leather discs charged with emery). Proof firing followed.

The bayonet and 29 other parts for the locks and mountings were hot forged from iron by smiths wielding sledges. The mounting forgings were passed to filers to file to shape and punch in the required holes. The filed parts were then ground, probably on powered wheels at the Water Shop, and returned to the filers for straightening. The trigger guard was hollow milled on its two ends, probably after filing, and threaded so that it could be attached to the trigger plate. The mountings were then polished at the Water Shop.

Heads were forged on the wood screws and the side screw and slit with a power-driven circular saw. Although Whiting says that the side screws were hollow milled with power machinery, this is not confirmed by examination of a Springfield musket made in 1812 and now in the Armory Museum; the side screw in this musket had been filed to an approximately cylindrical shape. The thread on the side screws was cut with a die by hand. (Edit. - Some extant muskets from the period, however, do possess side screws as described by Whitney.)

There was only one power-tool operation on lock parts: a hollow mill was used to form the arbor and pivot and the sides on the tumbler.[820] The tumbler was subsequently filed around its perimeter,

[819] Ibid, p. 247.

[820] This process is described by Battison.

where filing in the notches was a particularly critical operation. The other lock parts went from the smiths to the filers, whose work is described as divided into "eight branches." We take this to mean that eight different armorers filed parts that were eventually assembled into one lock. There is no evidence as to whether or not filing jigs were used. Once all the parts for a lock were brought together, they were filed until they worked smoothly with each other; they were then stamped with identifying numbers, case hardened, polished, and assembled into the finished lock.

Walnut stock blanks were received at Springfield from the Army office in Philadelphia. They were shaped and finished by stockers working with traditional hand tools and sandpaper. There is no evidence of who did the final assembly of muskets, but it was probably done by the stockers since the stock had to be fitted to the individual lock and barrel.

There were inspections at various stages of the manufacturing process. The barrel was inspected by the Master Armorer after it was bored, after it was ground, after proof firing, and again at the time of assembly into the completed musket. Lock parts were inspected after forging and after filing; ramrods, after tempering and after polishing. The completed musket was disassembled to permit determination of whether or not the fit to the stock was good. It was re-examined after final assembly. All of these inspections were carried out by visual examination or, for the completed lock, by trying its action. The use of gages is not mentioned although there must have been at least a gage of some sort to check the caliber of the bore. Artifactual evidence could be used to learn how effective these inspections were and what standards of dimensional tolerance and finish the work was held to, but the necessary examination of surviving examples of Springfield products have not yet been made. Visual inspection would have been ineffective in detecting faulty case hardening; a file test would detect a soft part but not those with an excessively thin case or overhardened. Faulty heat treatment was probably a major cause of subsequent failures of lock parts in service.

Whiting's report shows that the character of the work done at the Armory had not changed much since 1795; it remained basically hand work done without gages and perhaps without filing jigs. Power-driven tools were now used for some of the heaviest but less critical tasks, such as rough-boring barrels. The labor of barrel welding was heavy but the quality of the arms was particularly

sensitive to the quality of the welding. This work continued to be done by hand, probably because of mistrust of trip-hammer welds. The first, tentative steps towards the use of machine tools for the finer work, such as milling tumblers, were just being undertaken at this time.

Roswell Lee and Mechanization

With the appointment of Roswell Lee as superintendent in April 1815, a period of new interest in mechanization began at the Springfield Armory. The first development was the use of water power to relieve the heavy labor of making and welding the iron tube for the barrel. By 1816 a rolling mill was in place in the Middle Water Shops for preparing barrel skelps. This mill may have had limited capacity since through at least 1825, according to the payroll records, men were paid for "cutting, rolling and drawing scalps" (sic., skelps), which suggests that further hammering ("drawing") was required after rolling. Asa Waters started using trip hammers with semicircular dies for barrel welding at his works in Millbury about 1808,[821] and this technology was transferred to Springfield with the installation of one welding hammer in 1815. By 1816, four trip hammers for barrel welding, operating at 400 blows per minute, were in place at the Middle Water Shops.[822] There is no known description of the Armory trip hammers, but they were probably similar to those shown in drawings prepared some years later by James Burton and now preserved at Harpers Ferry National Historical Park; one hammer is for "bending barrel plates" and the other for "welding barrels." They are built on massive wooden frames and have a hammer beam about nine feet long. The hammer for bending is driven from a horizontal shaft with four cams while the hammer for welding has six cams, which would give more rapid blows. A saving of 27.5 cents per barrel resulted from the use of the trip hammer for welding, 11.5 cents on labor, 8 cents on the one pound less iron consumed, and 8 cents on the coal saved. Lee also found that barrels welded with the trip hammer burst less often than those welded with hand hammers. A year later, trip hammers were also being used to forge and round ramrods.[823] The improved productivity achieved by the use of power hammers is shown by the decrease in the percentage of the total labor force in making a musket that was devoted to welding from as much as 29% in 1811 to 4% in 1820 (Table 7.1).

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[821] Lee to Bomford, June 27, 1818, RG 156/1351.

[822] Lee to Wadsworth, December 24, 1816, RG 156/1351.

[823] Lee to Wadsworth, February 6, 1817, and Lee to Bomford August 1, 1821, RG 156/1351.

A second step in the mechanization of barrel making was the introduction of barrel turning lathes. An 1848 description of barrel making reported that the as-welded barrel, which weighed 10.5 pounds, was reduced to 4 pounds when finished. Thus, a great deal of metal had to be removed. This task was probably more difficult in the 1820s and 1830s than in 1848: before the introduction of lathes, the welded barrel had to be made smooth and round by grinding and filing. Grinding was a slow process that was detrimental to the artificers' health through inhalation of rock dust and dangerous because the large grindstones used were liable to burst along cracks initiated by wedges driven between the stone and shaft to get a tight fit.[824] Turning the outside of a long, thin tapered tube, such as a musket barrel, with a lathe requires solutions to two technical problems. First, adequate support for the work near the cutting tool must be provided. In a conventional lathe, the work is supported only at the ends; when the cutting tool moves along the tube, the work is likely to spring away from the tool. To prevent this, traveling support for the barrel that will follow the cutter is needed. Second, a mechanism must be provided either to offset the barrel, or to advance the tool inwards as it moves along the barrel, so as to form the taper.

Sometime before 1806 David Wilkinson constructed a lathe with a screw-driven carriage suitable for industrial use,[825] and lathes based on this principle were later judged of such value to the national armories that Wilkinson was awarded $10,000 by Congress in 1848. Further development of the Wilkinson design was needed for barrel turning. In the years 1816-9 five different kinds of barrel turning lathes were developed by American inventors, several of which were patented.[826] In 1818 Thomas Blanchard designed a cam motion for the barrel lathe patented by Asa Waters, which is said to have permitted the flats on the sides at the breech end of the barrel, as well as the taper, to be turned. Roswell Lee allowed trials of this machine at Springfield, but believed that more development was needed, preferring a machine based on the Dana and Olney patent and made by the Springfield Manufacturing Company.[827]

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[824] Marco Paul's Adventures in Pursuit of Knowledge, Springfield Armory.

[825] Robert S. Woodbury, Studies in the History of Machine Tools, p. 72.

[826] Merritt R. Smith, Harpers Ferry Armory and the New Technology, p. 117.

[827] Lee to Whitney, July 18, 1818, and Lee to Evans April 3, 1821, RG 156/1351.

The surviving descriptions of the different barrel lathes developed early in the 19th century are not sufficiently specific to permit analysis of their mechanisms or evaluation of the designs. Descriptions of the first attempts at barrel turning at Springfield show that the necessary rigidity for adequate support of the tool and work was not easily attained with the wooden construction then used for machine tool frames. Considerable tinkering was needed at Springfield to get a lathe to do useful work but barrel turning became a production process in 1818.[828]

The manufacture of barrels was further mechanized by the erection of a machine for "draw grinding" at the Upper Water Shops in 1819.[829] This machine was designed and built by Thomas Blanchard, who also supplied a machine for turning flats on the butt end of musket barrels, in 1818.[830] By analogy with draw filing, we infer that "draw grinding" was longitudinal grinding of the barrel with a power-driven wheel. In 1821, an improved barrel boring machine with a carriage moved by screws was in use.[831]

The power-driven tools for manufacture of lock parts brought in during the first years of Lee's administration (as enumerated by James Dalliba)[832] were:

> A water powered machine for "striking (at one blow each) bands, side plates, guards, and triggers from rolled iron." This probably was a weight lifted with the aid of water power and arranged to drop so as to strike a single blow on a die of shape appropriate to the part being made.
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> Four "drilling and milling machines (perpendicular) ... which greatly facilitates the drilling generally of the parts of muskets, but particularly the lock plates, and drills every one precisely similar." These would have been drill presses and were probably used with a metal

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[828] Smith, p. 123.

[829] James Dalliba, "Armory at Springfield," American State Papers, Military Affairs, Vol. III, p. 553.

[830] Blanchard to Lee, June 2, 1818, RG 156/1362; Lee to Stubblefield July 11, 1818, RG 156/1351.

[831] Smith, p. 96.

[832] "Armory at Springfield."

jig to locate the drill for each hole to be made in the lock plate, after the manner of Honoré Blanc. If so, this was a change in manufacturing technology from 1810, when the holes in the lock plate were punched. Much better control over the form and placement of holes could be attained by drilling. With the drill replaced by a hollow mill, the same machine could be used (without the jig) to shape the pivot and face of the tumbler.

Machines for milling and slitting the heads of pins "extended." In 1819 "pin" meant what we now call a screw. The head and body of a screw could be formed by two hollow milling operations and the slot cut with a circular saw. We have found supporting artifactual evidence in the side screws of a Springfield musket made in 1830 which were hollow milled. The milling machines mentioned by Whiting[833] were probably unequal to this task (as is shown by the presence of hand-filed side screws in an 1812 musket). We infer that the hollow milling machinery introduced in Lee's first years at the Armory was of the heavier construction needed to cut these relatively large screws.

Machines for turning the bayonet socket. This would have been a lathe used to turn the outside of the bayonet socket; it might have been used to bore the inside diameter, which had to be a good fit to the muzzle of the barrel. (Poor fits here were one of the major complaints about Springfield muskets made in 1819).[834]

Machines for boring the pan. A power-driven spindle with a shaped cutter for making the cavity in musket pans was designed in France in 1762;[835] the same design was probably used at Springfield.

Machines for milling the cock pins and rammer heads. Edwin Battison infers that these machines operated by clamp milling, in which a stationary, shaped cutter is closed around a revolving workpiece.[836]

[833] Whiting to Eustis, January 13, 1810.

[834] R.L. Baker, "Report of an Inspection of 100 Springfield Muskets 1828," SANHS.

[835] Fremont, p. 25.

[836] Battison.

We think it likely that the machine processes in this list were also in use at other armories; at least there is no evidence that any of them were devised at Springfield. Clamp milling, about whose antecedents we know little, is a possible exception. The mechanized operations described in Lee's list of all the steps in manufacturing a musket in 1825 could be done with the equipment already described above.[837] Once all these machines were in place, by about 1821, further mechanization of metal working at Springfield until about 1834 seems to have consisted of the addition of more machines of the same design since these constitute most of the machinery listed in the Armory inventory of 1834. In that year the technique of plain milling was first used.[838] There are several possible reasons for a slowing of technological change in machining during these years. First, it appears that all of the water power available at that time was utilized (see Chapter 4). Second, cutting wrought iron with carbon steel tools (the only kind then available) is relatively more difficult than cutting low carbon steel, and the limitations of the cutting tools may have made more extensive use of metal cutting machinery unattractive. The most important reason, however, is that the limits of the metal cutting that could be done in production with machines built on wooden frames, or composite wood and metal frames, probably had been reached. Wood is not stiff enough to provide the structural rigidity needed for any but the lightest metal cutting operations on a production scale for small arms.

Mechanization through 1820 at Springfield was primarily of the first kind described above, in which power is substituted directly for manual labor with little change in the character of the work done, but a start had been made on the use of mechanization of the second kind. Most of the mechanization was in barrel making, where the heaviest manual labor was required in the old method of working. Significant improvements in quality and reductions in cost were achieved. The water power needed to mechanize the heaviest work in making muskets appears to have fully utilized the power resources available at the water shops.

Mechanization of metal cutting operations at Springfield under Roswell Lee receives much attention

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[837] C. Meade Patterson, "Musket-making operations at Springfield Armory in 1825."

[838] Fitch, p. 25.

in accounts of the history of the Armory, probably because the descriptions by Dalliba and Lee are well known. The novel metal cutting machines introduced were the barrel turning lathe and, possibly, the clamp mill. However, analysis of the data in the work returns and payroll records of the Armory shows that the overall effect of this machinery on manufacturing operations was small. Between 1811, 1820, and 1830 the percentage of the total labor devoted to milling and boring hardly changes while the percentage used in filing increases (Table 7.1) Instead of a reduction of hand-work, there was a shift of effort away from welding and grinding and into filing. The significance of the mechanization of metal cutting in this period is primarily the demonstration of what might be accomplished rather than in significant changes in the distribution of labor.

Manufacturing Procedure in 1825

By 1825 the first stage of mechanization had been completed and a description of the methods used to make a musket can be pieced together from the several reports.[839] We also have a detailed report on the quality of the muskets made.[840]

There were 244 armorers (204 in 1810, for comparison) who completed about 45 muskets per day, so that the labor input was 5.4 man-days per musket, only slightly less than the 6 man-days in 1810. The armorers are listed under 17 occupations (Table 7.3) which is about the same number as in 1810.

Table 7.3

SPRINGFIELD PERSONNEL AND OCCUPATIONS OF ARMORERS IN ABOUT 1825

Armory Management

1 Superintendent (R. Lee)	4 Clerks
1 Master Armorer (A. Foot)	6 Assistant Master Armorers
1 Paymaster	3 Water Shop foremen
1 Storekeeper	

[839] Dalliba; Patterson; U.S., Ordnance Department, Regulations for the Inspection of Small Arms, 1823.

[840] Baker.

Occupation and Number of Armorers

52 Jobbers	9 Drillers, millers & turners
42 Lock filers	8 Mounting forgers
35 Stockers	7 Barrel borers
18 Forgemen & triphammer under hands	7 Barrel welders
14 Finishers	5 Barrel finishers
12 Mounting filers	5 Lock forgers
10 Grinders	6 Trip hammer men
2 Ram rod forgers	2 Bayonet forgers
10 Polishers	

Table 7.4 lists the manufacturing operations in making a barrel. The principal changes after 1810 were the use of trip hammers in place of hand hammering for welding, and the use of barrel turning lathes. The trip hammers were located in both the Upper and Middle Water Shops, and were designed to run at the high speed of 400 blows per minute for welding. It is of interest to note that, despite the use of turning lathes and other machinery, filing was still the largest item of expense in making a barrel after welding.

Table 7.4.

OPERATIONS AND LABOR COSTS OF MAKING A MUSKET BARREL IN 1825[841]

Cutting and drawing the skelp	4.5 cents
Welding	26.0
Nut boring	5.5
Counter boring and milling	1.2
Smooth boring	7.2
Turning	4.7
Grinding	2.6
Proofing	5.4
Filing	11.6
Sighting	3.2
Straightening	6.0

[841] Lee to Bomford, July 1, 1825, RG 156/1351.

In 1810 the only tasks performed by machine on the other parts of the musket were hollow milling of tumblers and slitting screws. By 1825 this list had expanded, to include:

> Cutting the bands and side plate
>
> Drawing the ramrod
>
> Welding the bands
>
> Boring the bayonet socket and the pan
>
> Turning the bayonet socket and the head of the side screw
>
> Milling the breech plug, bayonet socket, guard bow, band spring, side screw, tang screw, butt plate screw, guard screw, tumbler, bridle, cock pin, and lock screws
>
> Slitting the side screw, tang screw, butt plate screw, lock screws, guard screw, cock pin
>
> Threading the cock pin
>
> Drilling the barrel vent, bands, guard plate & bow, lock plate, frizzen, cock, tumbler, bridle, sear, upper jaw, cock pin, main spring, frizzen spring, and sear spring
>
> Punching the side plate, butt plate, and the square hole in the cock
>
> Countersinking the guard plate and butt plate
>
> Grinding the bayonet, ramrod, bands, guard, side plate, butt plate, and lock plate
>
> Polishing the bayonet, ramrod, bands, swivel, guard, lock plate, trigger, side plate, band spring, butt plate
>
> Turning, boring, inletting (the lock), fitting bands, fitting butt plate of the stock.

As shown in Table 6.5 in Chapter 6, the proportion of hand work in making a musket changed very little through this period. Thus it appears that, while powered machinery was being used for many tacks formerly done by hand, neither the amount of hand work nor the man-days per musket decreased significantly. From this we infer that the machinery probably relieved same of the physical drudgery of metal and wood cutting, but that the skill of the armorer's hand was still needed to make satisfactory parts after the machine work was done.

Case hardening of the trigger, side screw, tang screw, butt plate screw, guard screw, and lock plate were done in a shop built for the purpose at the Upper Water Shop. The bayonet, ramrod, main spring, battery spring, and sear spring (all made of steel) were quenched and tempered.

Some gages were supplied to individual artificers for testing their work, but it remains uncertain haw many were in use at this date. We infer that the final inspection procedure used at Springfield would have been similar to that used for contract arms, which involved the following steps:

Diameter of bore of the barrel tested with two plug gages

Outside diameter of the barrel tested with gages at the breech, middle, and muzzle

Straightness of barrel tested with stretched string

Temper of the tang tested with a fine-cut file

Lock gage (a receiving gage) used to test size of lock plate

Lock inspected visually and operated

Bands verified by gage

Fall of stock gaged

Degree of seasoning of wood in stock tested by rolling up a chip

Diameter of ramrod verified by gages adjusted to the pattern musket

Temper of ramrod tested by looking for offset after springing the rod 6 inches

Temper of bayonet tested by looking for offset after flexing it 1 inch

Bayonet passed through scabbard gage

In this procedure a total of 11 gages were used. The faults found in these muskets by Benjamin Moor were described in Chapter 3.[842]

[842] Baker.

Second Generation of Metalworking Mechanization

The number of metalworking machines in use at the Springfield Armory appears to have increased in the years after 1821, but we find no evidence that any new metalworking technology was introduced until about 1834, when machines capable of milling flat surfaces were first put into service. However, important developments in mechanization took place at Simeon North's factory at Middletown, Connecticut, at other private armories, and at John Hall's Harpers Ferry rifle works. Because the documentary and (so far as it has been studied) material evidence of these developments is particularly sparse, we can present only an imperfect account of them at this time.

Simeon North and Nathan Starr

We noted in Chapter 3 Simeon North's important contribution to interchangeable manufacture, beginning (to an undocumented extent) with his 1813 contract for pistols with uniform parts, and continuing with his successful production of Hall rifles. Smith and Battison have presented documentary evidence showing that the first milling machine for cutting flat surfaces known to have been used in the United State was probably made at North's Middletown factory.[843] This machine was seen in 1851, still in use, but located in Robert Johnson's arms works near North's factory. Smith also found evidence that in 1829 Nathan Starr, whose factory was half a mile downstream from North's, had a miller with a horizontal spindle supported on three bearings, and fitted with cutters having the shape of the desired surface. Such a machine could, for example, be used to cut the profile of a lock plate.[844] Also in 1829, William Smith and William Ferry, master machinists at North's works, built a miller in which the spindle could be adjusted vertically. This would allow the depth of the cut to be adjusted as desired.

This evidence shows that the principal elements of the milling machine later made commercially under the name "Lincoln," and widely used by armories and other industries, had been developed and put into production work at the arms factories spread along the West (now Coginchaug) River just outside of Middletown, between 1816 and 1830.

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[843] Merritt R. Smith, "John H. Hall, Simeon North, and the Milling Machine: The Nature of Innovation among Antebellum Arms Makers"; Edwin A. Battison, "A New Look at the `Whitney' Milling Machine." This machine was described by Edward G. Parkhurst, "One of the Earliest Milling Machines."

[844] Smith, "John H. Hall.."

John Hall

John H. Hall almost certainly knew of the Middletown developments in milling technology. He built and patented new metal cutting machines, for his rifle works at the Harpers Ferry Armory that probably represented an additional technological advance in metal cutting.[845] This machinery was used to make the U. S. Rifle Model 1819, a breech loader of Hall's design. Unfortunately, the Patent Office fire of 1836 destroyed the patent drawings of Hall's machines, and the demolition of the rifle works in 1861 destroyed the machines themselves. Only a limited description can be pieced together from surviving documentary evidence.

The best (but not very explicit) account of Hall's machinery is the 1827 Carrington report on the rifle works, prepared in response to a Congressional resolution calling for information on the manufacture of the M1819 rifle.[846] The report stressed the unusually heavy and accurate construction of the inspected machines, many of which were built on cast iron frames.[847] The frame technology was not new since the Portsmouth pulley-block machines and the "Middletown milling machine of 1818" were all built on cast iron frames.[848] Nevertheless, the use of iron frames undoubtedly helped Hall to overcome the lack of structural rigidity that was one of the most serious limitations of earlier production machine tools.

Hall's machines for drilling and hollow milling used vertical spindles, as did the earlier Springfield machines, but were built on iron frames. (The Springfield machines were probably on wooden frames.) They were fitted with positioning points for fixtures to hold the work, and had provision for a vertical screw adjustment of the table, which could be locked in place for setting the elevation of the work.[849] (The Carrington report implies that this machine had two horizontal spindles.) Despite

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[845] Ibid.

[846] Carrington, Sage, and Bell to Bomford, January 6, 1827, reproduced in U.S., Ordnance Department, A Collection of Annual Reports and Other Documents Relating to the Ordnance Department, Vol. I, pp. 153-57; Smith, Harpers Ferry, pp. 200-208.

[847] Fitch, p. 25, described the machines as "excessively solid and heavy;" see Smith, Harpers Ferry, p. 228, on the cast iron frames.

[848] Cooper, "The Portsmouth System of Manufacture;" Robert S. Woodbury, History of the Milling Machine, p. 20.

[849] Smith, Harpers Ferry, p. 235.

the uncertainty about its actual construction, this machine appears to represent an improvement over the earlier models of drilling and milling machines in strength and in provision for fixtures to hold the work.

The Carrington committee also mentioned three types of metal-cutting machines that seem to have been of novel construction and used "cutters and saws" to shape components for the Hall rifles. They were described as "straight," "curve," and "lever" cutting machines. The straight cutting machine was said to be able to form either a plane or a straight and ribbed surface; thus, it was probably what we would now call a plain milling machine. The flat surfaces would have been made using a straight milling cutter; the ribbed surfaces, with either a cutter having a curved contour, such as those made by Vaucason before 1760,[850] or ganged straight cutters. The curve-cutting machine, which produced surfaces with either single or double curvature, was probably a profiler. Fitch believed that the lever cutting machine, which is not described in the Carrington report but is said to have been used to make the mortise through the receiver for the cock and to bore the pan, was similar to what would have been called a hand miller in 1880.[851] There seems to be little doubt that these machines were heavier than any yet built in the United States. Fitch also stated that these machines were run by hand,[852] while the Carrington report implied, but did not state, that they were driven by water power and had power feed with automatic stops. Whichever is true, these machines, together with those made at Middletown, may be considered as the forerunners of the heavy milling machines needed for production work on metal parts. Smith has shown how information about milling technology could have been promptly exchanged between the New England armories, and with Harpers Ferry, through the migration of Armory managers and artificers.[853]

The Carrington committee reported seeing demonstrations showing that metal parts for the M1819 rifle could be made at lower cost, and more accurately, by Hall's machinery than by experienced artificers working with files. The smaller parts of the M1819 rifle mechanism are not very different

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[850] Fremont, p. 22.

[851] Fitch, p. 25.

[852] Ibid.

[853] Smith, "John H. Hall..," and Harpers Ferry, pp. 242-47.

from the lock parts of the flint and percussion arms made at the Springfield Armory. We will see in the following pages that more than two decades after the Carrington report was written, Springfield (and other armories) had not succeeded in using machinery for the production of small arms components as Hall is reported to have done. In view of the rapidity with which developments in manufacturing technology were exchanged among armories at this time, it is difficult to understand why this should be so.

Several explanations may be suggested. It may be that the descriptions of the capabilities of these machines, by the Carrington committee and others, have not been accurately interpreted. This seems unlikely but, since much more is implied than is actually stated in the Carrington report, it is possible. It may be argued that Hall's machinery was specifically designed to produce the M1819 rifle and was not useful for the work to be done on other model arms. Although the breech block and the receiver of the M1819 rifle are of quite different shape than the parts of muzzle-loading arms, it appears to us that milling operations could have been equally useful in making both types of arms.

We suggest two more likely reasons. One is that Hall's machinery may not have been economic to use at other armories—that it was not capable of achieving a sufficient reduction of labor costs to justify its initial cost. The test performed by the Carrington committee showed that the work done by the machines could be done by hand in only 1/3rd more time. It is likely that, in order to achieve a reasonably long life for the carbon-steel milling cutters used, only light cuts could be taken. If, as seems likely, the cutters had the small, file-like teeth generally used in the first part of the 19th century,[854] heavy cuts would have been impossible because of inadequate clearance for the chips. Either resharpening or making new cutters would have been costly, particularly in the absence of machines for cutter grinding The second reason is that our examination of the Hall rifles in the Museum, Springfield Armory NHS, shows that, in each example in the collection, all the surfaces of the breech mechanism that require a close fit were finished by hand filing. We conclude from this evidence that the milling equipment used by Hall was not capable of attaining the high standard of precision that he required in his finished product. Since filing to gage was still required after machining, it was probably not economic for other armories to make a large investment in specialized machine tools. Comparison of costs and products at Hall's and North's works, when both

[854] See illustration in Fremont, p. 22.

were making the same model rifle would probably throw further light on these problems.

Plain milling at Springfield and the beginnings of the third stage of mechanization

According to Fitch, two new types of milling machines were introduced at Springfield about 1834.[855] One had a fixed spindle and was used for milling the flat surfaces of wrenches; the other, devised by Thomas Warner, was for milling lock plates to a uniform thickness. Fitch believed this to be similar to the one with an adjustable spindle then in use at one of the armories in Middletown. Roswell Lee and John Robb frequently sent artificers from Springfield to the armories near Middletown to examine the machinery there and, in same cases, to procure castings.[856] The Armory recruited experienced artisans from the Middletown area; North's master machinist, William Smith, went to Springfield in 1837, for example. The new milling technology developed in Connecticut was brought to Springfield through these exchanges. Warner's machine for milling lock plates was probably a development of the machine that was in use built at North's armory in 1829. However, there is not sufficient evidence to sort out the antecedents of the Springfield machines with confidence, or to infer what their designs were in any detail. The only miller from this period for which there is a description is a machine used in the Gay & Silver works in Chelmsford.[857]

The best evidence on the machine tools used at Springfield in the 1830s and 1840s is in the available Armory inventories, which cover the period 1835-44,[858] and the annual reports which list machines acquired from 1845 to 1859.[859] The inventories for 1841 and 1844 list the function of each milling machine. Some of these machines can be traced back in the earlier inventories through the values assigned to the machines, which change little from year to year.

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[855] Fitch, p. 25.

[856] Smith, "John H. Hall.."

[857] Woodbury, History of the Milling Machine, p. 28.

[858] Inventory of Public Lands & Buildings, Ordnance and Ordnance Stores, Machinery, Tools and Materials on hand at Springfield Armory, Dec. 31, 1834; Inventory of Ordnance and Ordnance Stores on hand at Springfield Armory in charge of the Master Armorer, Dec. 31, 1835; Inventory of Tools at the Springfield Armory, Sept. 30, 1839; Number of Tools on hand per inv. Sept. 30, 1842; Inventory of Tools in...Service, June 30, 1844. SANHS.

[859] ARSA 1845-59.

The 1835 inventory includes 17 millers with an average value of $200 each and two listed separately with a total value of $800. It is probable that the 17 machines are the hollow and clamp millers introduced in the 1820s, and that the two more expensive machines are the two machines mentioned by Fitch. Plain milling would require a heavier, and therefore more costly, machine.

There was a substantial increase in the number and value of machine tools at Springfield between 1834 (100 machines at $7860 plus a rolling mill at $14,000)[860] and 1838 (119 machines at $16,700 in addition to the rolling mill). Six engine lathes, three drilling machines (one a drill press with a cast iron frame) and two "cutting engines" (not otherwise identified) along with a number of lesser machines were added. According to Fitch,[861] Robbins & Flagg of Millbury built a machine for milling the irregular edges of lock plates for the Springfield Armory shortly after 1835. Among the machines first listed in the 1838 inventory is one said to be used for milling the edge of the lock plate and valued at $1170; we infer that it is the Robbins & Flagg machine. There is no description of this machine, but we can be quite confident that it had a horizontal spindle and a cutter made with the profile of the work to be cut. If this machine was based on a design from the Hall rifle works or Nathan Starr's factory, it means that there was at least a 10-year delay in the transfer of this milling technology to Springfield. It appears to us that milling technology (i.e., the design of both the machine and the cutter) suitable for the reliable and efficient production of metal parts for small arms was being developed at about the same time in a number of New England shops in the 1830s, and was then adopted at the Springfield Armory. The Armory's move toward the use of larger, heavier and more powerful cutting machines in these years is shown by the increase in the cost of their milling machines in just four years, from an average cost of about $200 before 1834 to machines costing $400 in 1835 and $1170 in 1838.

There is little further change in the inventory of machines at the Armory in 1838 and 1839. During the 1830s, the largest investment in machinery made at Springfield was for the rolling and slitting mill. Engine lathes and drill presses were acquired and the new metal cutting technology introduced was plain milling, brought in through the purchase of machines.

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[860] The rolling mill was designed by Henry Burden, and later used for reworking scrap iron; see Bessey's Springfield Directory for 1851-2, pp. 157-67.

[861] Fitch, p. 25.

Thomas Warner and Cyrus Buckland

The gradual introduction of more machine tools at Springfield in the 1830s was interrupted by a large change in the number and type of machine tools between 1839 and 1842. Thomas Warner, Master Armorer from August 1837 to the end of 1841, began work in 1837 on new machinery for making the M1840 musket.[862] Most of this machinery entered the inventory between 1839 and 1842. The latter inventory does not specify whether or not these were made at the Armory but, since construction of machinery continued at the Armory at least until 1859 according to the Annual Reports, it is likely that a significant number of the new machines were made at the Armory. Five of the machines are specified as having iron frames; since it was considered worth mentioning this in the inventory, it is likely that the use of iron frame was still sufficiently uncommon to call for remark.

The new machines listed in 1842 include:

Boring blanks for rough, smooth, and finish boring barrels, counterboring barrels, and boring bayonets--9 machines

Several drill presses including one with five arbors for lockplates-8 new and old machines providing a total of 19 spindles

(Drill presses were apparently used for hollow milling as well as drilling since one is specified for the guard bow, which has no holes in it.)

Five engine lathes

A new multiple spindle machine for screw cutting

Eight new milling machines

(Of the total of 28 milling machines in the inventory, 13 appear to be plain millers and 15 clamp or hollow milling machines. Four of the new millers were for bayonets, with an average cost of $630. These are the machines described by Fitch as having vertical adjustment of their spindles. They were designed by Thomas Warner and eliminated the hazardous task of shaping bayonets on

[862] Derwent S. Whittlesey, "The Springfield Armory," Chapters 5 and 8.

grindstones. These are significant as the forerunners of the Lincoln miller, which a decade later became one of the most widely used of all machine tools.)

A cutting engine for mills, a fairly expensive machine at $465

The engine is described as for "gearing or mills" which we interpret to mean that it was capable of cutting gear teeth but was used for making milling cutters. This is a particularly important acquisition because it means that the milling cutters used in 1842 were no longer of the rotary file type, which had very fine teeth, but were of the modern design, with large teeth for taking a heavy cut while turning at low speed. The large teeth allow higher cutting forces and provide better clearance for the chips; they are essential for the efficient removal of significant amounts of metal. As noted previously, we believe that the lack of such cutters limited the utility of Hall's milling machinery.

Unchanged in the 1842 inventory were the grindstones, most lathes (non-engine lathes, that is), and the clamp and hollow milling machinery. The inventory shows that there was a major change in mechanization at this time; millers and engine lathes appeared while grinding becomes less important. Table 7.5 (below) lists the parts on which milling operations were performed. Further indirect evidence on the more extensive use of machinery for metal cutting comes from the ratio of "mills" (presumed to mean milling cutters) to milling machines; it averages 8.5 for the years 1834-39 but increases to 23 by 1843. Most of the machines are designated for a specific part, such as the upper barrel band. Several cutters might be needed to do all the operations on one band and, as the machines were worked harder, more spare cutters would have to be kept on hand to allow for sharpening.

Table 7 .5

LIST OF MILLING OPERATIONS, 1842[863]

Lock plate, sides	Breech, tang
“ “ edges	“ plate
Cock, side	Upper band, sides
“ edge and comb	“ “ rod hole

[863] "Number of Tools... 1842," which lists these uses for the different milling machines on hand that year.

Battery	Middle band
Tumbler	Lower band
Sear	Butt plate
Mounting screws	Guard plate
Lock screws	Bayonet, socket
Springs	“ stud
Trigger	“ blade, 5 operations
Barrel, breech	
“ muzzle	
“ ends	

The style of the drilling machinery being built at this time (or shortly thereafter) is shown in the drawing of a "Drilling Machine, 3 spindles" by Burton (now at Harpers Ferry). It has a cast iron Doric column and a transverse shaft with a cone pulley that drives one of three vertical spindles by bevel gears. Adjacent spindles are driven by short belts off the central spindle. (One imagines that the use of these short belts would not have been very satisfactory.) The spindles are fixed but the table can be raised by a foot pedal working through a rack and pinion. Since there is one table, the machine could either drill three holes simultaneously or three different tools might have been kept in the spindles to be used in turn as required.

Burton's drawings also include a machine for "Milling and chamfering Musket Barrels." It has an iron frame and three horizontal spindles geared together and driven by a pulley on a central spindle. The barrel is placed on a sliding table advanced by a foot pedal and can travel about 1/5th of the barrel length. This machine may have been intended to perform three simultaneous operations on three barrels, but we think it more likely that it was used to do three operations in sequence on one barrel. "Milling" in this case probably means what we would now call facing the end of the barrel. Another machine for "1st boring and milling Bayonets" has one spindle and a frame similar to that described previously. Judging from the cutter illustrated, "milling" was probably a facing cut. The direction of machine design suggested by these drawings is the construction of special purpose machines provided with multiple spindles that would permit a sequence of operation to be carried on without moving the work from one machine to another. This seems to be a characteristic of the second stage of Armory mechanization.

By 1841, the system of making gun parts that was to persist well into the 20th century at the

Springfield Armory was established, largely through the work of Thomas Warner and Cyrus Buckland, the Master Machinist who continued some of Warner's work. Parts were first forged about 1/8th-inch oversize and then milled close to their final shape.[864] They were then filed to gage in filing jigs. The importance of filing is shown by the continued presence of large numbers of filing jigs in the inventories (there were on average always about 1.5 jigs per filer), and by the data on distribution of labor in Table 7.1.

Filing remained the dominant category of labor until after 1864, while the proportion of labor spent on milling increased steadily but gradually. Drilling increased somewhat, but the relative effort devoted to boring, turning, and grinding hardly changed.

The new machining technology introduced for making musket parts in the years to 1842 seems to have originated only in part at the Springfield Armory. Armory mechanics adapted new machinery being developed throughout New England, applying it to a well-organized production process. Merritt R. Smith has argued that the advances in milling technology were incremental and involved the contributions of many individuals.[865] The additional evidence that has come to light since 1973 supports this interpretation. Turning technology (lathes) has received less attention from historians, but we believe that the same generalization applies.

By 1842 the Armory had in place a system of production based on a progression of forging, milling (or turning), filing, and gauging operations to produce a uniform product. Although technically somewhat derivative, this system was probably unusual in its scale and completeness among American industries. Other armories were, however, producing equally good products—for example, armories scattered between Windsor, Vermont, and Philadelphia had achieved interchangeability in the M1841 rifle. We have found no data on the relative production costs at these different armories.

Manufacturing Procedure for 1852

Contemporary and some later reports allow us to infer Armory manufacturing procedure in the early

[864] E.A. Dixie, "Same more antique machine tools."

[865] Smith, "John H. Hall..."

1850s, reflecting the advances made c1837-42.[866] Armory production in 1850 included 21,000 M1842 percussion muskets and 2,000 musket-cones; additionally, 57,272 muskets were altered from flint to percussion ignition, and 119,757 extra cones, 93,908 screw drivers, 41,682 percussion harmers made.[867] Table 7.6 presents materials and supplies probably used directly in the fabrication of small arms in 1850. The materials are about the same as those used in the 1820s, although the ratio of steel to iron used increased modestly since 1823, from 10% to 14%. Among the supplies, the sulfuric acid would have been for pickling iron parts (removal of scale); the oil for lubrication and as a quenching medium in heat treatment.

Table 7.6

MATERIALS AND SUPPLIES USED FOR MAKING SMALL ARMS IN 1850[868]

Materials	Supplies
Refined iron, 446,628 lbs	Sulphuric acid, 2,823 lbs
Iron Wire, 1,079 lbs	Sperm & whale oil, 2,380 gal
Cast steel, 63,146 lbs	Files, 8,613
Shear steel, 651 lbs	Sand paper, 326 quires
Timber, 32,204 ft	Grind stones, 52,634 lbs

Fuel is not listed under “supplies” here.

Table 7.7 lists the machine tools in use at this time. The 30-hp steam engine on the Hill made it possible to do work there previously done at the Lower Water Shops. The increased number of milling machines, and their presence in the "filing shop," suggests that, although the millers were used for roughing cuts on forgings, lock parts were still being finished by filing. We note also the presence of specialized cutter grinders, an essential auxiliary since heavily used carbon steel cutters require frequent sharpening.

The descriptions of the Armory assert that, of the 400 operations in making a musket, most men do only one. (According to Table 6.5 in Chapter 6, 9% of the artificers did more than one kind of work

[866] Dixie; Bessey; Jacob Abbott, "The Armory at Springfield;" Ordnance Department, Ordnance Manual [1850].

[867] Bessey; ARSA 1850.

[868] Bessey, p. 158.

at this time and this percentage was unusually low in 1850.) The barrel scalp of Salisbury or Ancrom iron 2 ft long by 3 inches wide was drawn (elongated) and welded under trip hammers; 11 heats were used to weld the barrel, which was then bored with rotating augers in the boring banks to obtain a smooth interior. Boring and turning operations alternated as work on the barrel proceeded. The marks left by the turning tool were removed by grinding. Straightening was done with aid of a line in a window viewed with a mirror on the floor. This replaced the older method in which the bore was compared with a taut thread. In 1850, bayonets were milled; this replaced the older method of grinding on a fluted stone, which was very injurious to the health of the artificers.

The forged parts were still formed in swedges (die blocks containing cavities) struck by smiths wielding sledges. A substantial amount of metal had to be removed to reach final dimensions. For example, the forging for the lock plate was made 1/8-inch oversize on the perimeter and 1/32-inch too thick. It was then milled to the proper thickness, drilled, tapped, and filed in a filing jig consisting of iron and hardened steel plates. (The iron plates protected files from damage by contact with the steel plates that defined the outline of the part being filed; as they were worn by filing, they would have to be changed frequently.)

Table 7.8 lists the production workers' tasks. Since 57 milling machines were used by 26 millers, each artificer must have tended at least two machines if they were all in use at the same time. Lock filers (24) were almost as numerous as millers (26), showing that much hand finishing work was still needed. However, the number of files used per lock made had been reduced to 1/3, down from one per lock in 1823, showing that milling was used to remove most of the excess metal from the forgings before the filing began. No one is listed for case hardening iron or for heat treating steel; perhaps the annealers did this. It would be interesting to know what the "iron maker" did since we believe that the armory bought all of its iron.

We estimate from the quantities of materials bought, and the number and weight of metal in the arms made, that 2/3rds of the iron used went into chips and scrap in 1852, compared with 3/4 in 1823. This is a large loss rate and shows that not much progress had been made since 1823 in reducing the amount of metal cut away in making gun parts. Much of the waste was in making the barrel since the scalp weighed 10.75 lbs and the finished barrel only 4.25 lbs. The consumption of

grindstones (now used primarily for finishing barrels) was 2.3 lbs per barrel, down from 14.9 lbs in 1823. This suggests that the barrel turning lathes in use in 1850 were much more effective than those of 1823.

Table 7.7

MACHINE TOOLS USED IN 1851[869]

Upper Water Shop:	13 Boring banks	2 Barrel polishing machines
	9 Turning engines	1 Machine for buffing bayonets
	7 Large grind stones	2 Screw cutting machines
	4 Lathes	1 Punch press
	10 Milling machines	1 Wood planer
	1 Circular saw	1 Machine for splitting leather.
Middle Water Shop:	18 Tilt hammers	
Lower Water Shop:	1 Rolling mill	2 Tilt hammers
	1 Cutting shears	
Hill Filing Shop:	1 Boring bank	3 Machines for cutting screws
	1 Lathe	1 Machine for tapping cone seats
	2 Turning engines	3 Machines for drilling cones
	45 Milling machines	2 Machines for checking hammers
	11 Drill presses	2 Hammer-straightening machines
	1 Punch press	2 Milling cutter grinding machines
Hill Machine Shop:	1 Cutting engine	5 Planing machines
	9 Lathes	1 Machine for sawing, grooving wood
	5 Turning engines	5 Machines for making arms chests
	3 Drill presses	1 Machine for cutting bolt

[869] Bessey, p. 160-163.

4 Punch presses	1 Straightening machine
2 Milling machines	1 Slitting machine
1 Machine for shaving bridles	

(This shop made machines and tools)

Stocking Room: 14 Stocking machines

Table 7.8

PERSONNEL AT THE SPRINGFIELD ARMORY IN 1852[870]

	1 Master Armorer	11 Drillers
	11 Inspectors	3 Turners
	16 Machinists	3 Grinders
	18 Barrel forgers	11 Barrel filers
	7 Lock forgers	24 Lock filers
	8 Bayonet forgers	6 Bayonet filers
	2 Ramrod forgers	14 Mounting filers
	10 Mounting forgers	3 Appendage filers
	5 Appendage forgers	16 Polishers
	9 Assistant forgers	16 Stockers
	6 Annealers	1 Barrel finisher
	1 Iron maker	3 Mounting finishers
	14 Borers	3 Lock finishers
	26 Millers	2 Appendage finishers
Jobbers:	5 Smiths	2 Filers
	19 Carpenters	1 Mason
	36 Laborers	

In the inspection of barrels, the tolerance of cinder holes was much reduced from what it had been in previous years. By 1850, 56 gages (instead of the 11 used in 1825) were used to check dimensions, including 15 for the barrel, 15 for the lock, and 26 for the mountings and other parts. The types of gages used included length, groove, plug (standard, limit, and taper), tap and die, receiving, pattern (for lockplates), and apparatus for testing lock springs, stock gage, and some others for specific parts. Sufficiently good interchangeability allowed for the end of the production of lock parts in numbered batches in 1849.

[870] Ibid, p. 160.

Armory Mechanization c1842-1859

There was little change in the inventory of machinery for a few years after 1842, but this was followed by fairly steady, incremental growth in the number of machines until the advent of the Civil War. Figure 7.1 shows totals inferred from the increments for some classes of machines. The increase in the number of milling machines approximately parallels that in tilt hammers. This implies that both the forging and machining capacity of the Armory was being expanded. At the same time, the importance of grinding continued to diminish. Other machine tools, such as drill presses and engine lathes, also increased in number during this period. The only new types which appear in numbers are rifling machines, which were needed once production switched from smooth bore to rifled arms. In 1855 Cyrus Buckland invented an improved rifling machine that could complete a barrel in 25 minutes. The effectiveness of these machines is shown by the small proportion of labor used in rifling, only 1% of the total work done (Table 7.1).

The annual reports do not always distinguish between purchased and fabricated machines, but do make it clear that the Armory made many of its machine tools through this period. Some seem to have been experimental. One, a "shaving machine" was commenced in 1853 and was only finished three years later.

The growth in the number of machines after 1842 probably meant that each machine was used for only one operation. Changing the set up of tools and fixtures on each machine could be avoided in this way. Many machines would then be needed because many different cuts were required to shape most parts. By 1864 three milling operations on different machines were performed on the tumbler, three on the guard plate, and five on the lock plate, for example.[871]

The purpose of introducing more machines seems to have been reduction of labor costs. This is illustrated, for example, by Thomas W. Harvey's proposal to sell the Armory screw machines.[872] He based his sales pitch on a saving of labor costs that would pay for the machines within two years. In

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[871] Dyer to Ramsay, February 4, 1864, reproduced in U.S., Ordnance Department, A Collection of Ordnance Reports and Other Important Papers Relating to the Ordnance Department..., Vol. II, pp. 859-77.

[872] Harvey to Ripley, December 10, 1847, RG 156/1382.

his estimate, labor with his machinery would be only 28% of the cost of the iron for the screws.

Because of the many difficulties encountered with welding barrels under the trip hammer, Roswell Lee began experiments on forming and welding the skelp in rolls as early as 1825. To review and expand on the discussion in Chapter 5, the work was done by Henry Burden of Troy, New York, between 1825 and 1833, but did not result in a practical operation.[873] The Ames Company of Chicopee built machinery used in an attempt to weld barrels in rolls at the Armory in 1850, but in 1851 the attempt was pronounced a failure.[874] We believe that the difficulty encountered may have been due to lack of suitable iron rather than a deficiency in the machinery. The British committee that visited Springfield in 1854 described the system of making barrels by trip hammer then in use there as inferior to the rolling mill method used in England.

The English technique for making gun barrels had been developed in two stages, both occasioned by work stoppages caused by strikes. About 1810, the drawing of barrel skelps under trip hammers was replaced by a single rolling operation. Rolls with a circumference equal to the length of the skelp were used. A groove of increasing width and depth (corresponding to the desired form of the skelp) was cut in each roll so that the skelp could be formed in one pass through the rolls. About 20 years later a new process, in which the barrel was welded with rolls, was introduced. A skelp about one foot long was formed into a tube with grooved rolls and then, after reheating, welded by a further pass through the rolls. Subsequent passes were used to elongate the tube to the desired length. The welds obtained were superior to those made under the trip hammer.[875]

The Ordnance Department had been receiving reports on the English method for about ten years before Armory Superintendent James Whitney contracted with J.T. Ames early in 1858 to acquire for the Armory an English rolling mill and 50 tons of iron to use with it.[876] Armory correspondence traces subsequent developments. On June 19, 1858, Whitney wrote to C. & F. Thomson of Boston,

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[873] Paul Uselding, "Henry Burden and the question of Anglo-American technological transfer in the nineteenth century."

[874] Deyrup, p. 152.

[875] Charles Babbage, <u>On the Economy of Machinery and Manufactures</u>.

[876] Nathan Rosenberg, ed., <u>The American System of Manufactures...</u>, p. 64; Ames to Whitney 5 Nov 1857, RG 156/1365; Whitney to Ames January 1, 1858, RG 156/1351.

"...machinery for rolling barrels has not yet arrived from England." On the first of July, Whitney wrote Ames to arrange for the employment of William Onions of England to set up the machinery at Springfield. On November 1, Whitney, responding to a query from Ames, reported that proof tests had been done on the first lot of 100 barrels and that only one of these had failed; he observed that the rolling machine was regarded by the Master Armorer as a "perfect success." Thus, the roll-welding machine was set up sometime after July 1, 1858, and was in successful operation by November first, a remarkably short start up time for so complex a manufacturing operation. The effect of the introduction of welding in rolls on the productivity of the barrel welders was dramatic. In 1858 the average number of barrels welded per man was 4,767; by 1860 it had increased to 12,615.[877]

There are several points of interest in this story. One is that, as shown by the two failed attempts, the Springfield Armory appears not to have been well positioned to undertake the development of new manufacturing methods that involved sophisticated metallurgical technology (Chapter 5). However, once the necessary materials, skills, and equipment were obtained, the Armory exploited them in large scale production very quickly. The transfer of this technology was critically dependent on bringing in an artificer skilled in its use. During the Civil War, Prescott observed, "The operation of rolling the barrel is not only a very important and valuable one, but very difficult of acquisition, the knowledge appertaining to its practical working having been wholly confined to one person in the country previous to breaking out of the Rebellion."[878] In England, the roll-welding technique developed for gun barrels was promptly adapted to the manufacture of iron pipe for domestic gas and water supply.[879] It would be of interest to know if a similar diffusion of this technology took place in the United States.

[877] Deyrup, p. 247.

[878] G.B. Prescott, "The United States Armory."

[879] Babbage.

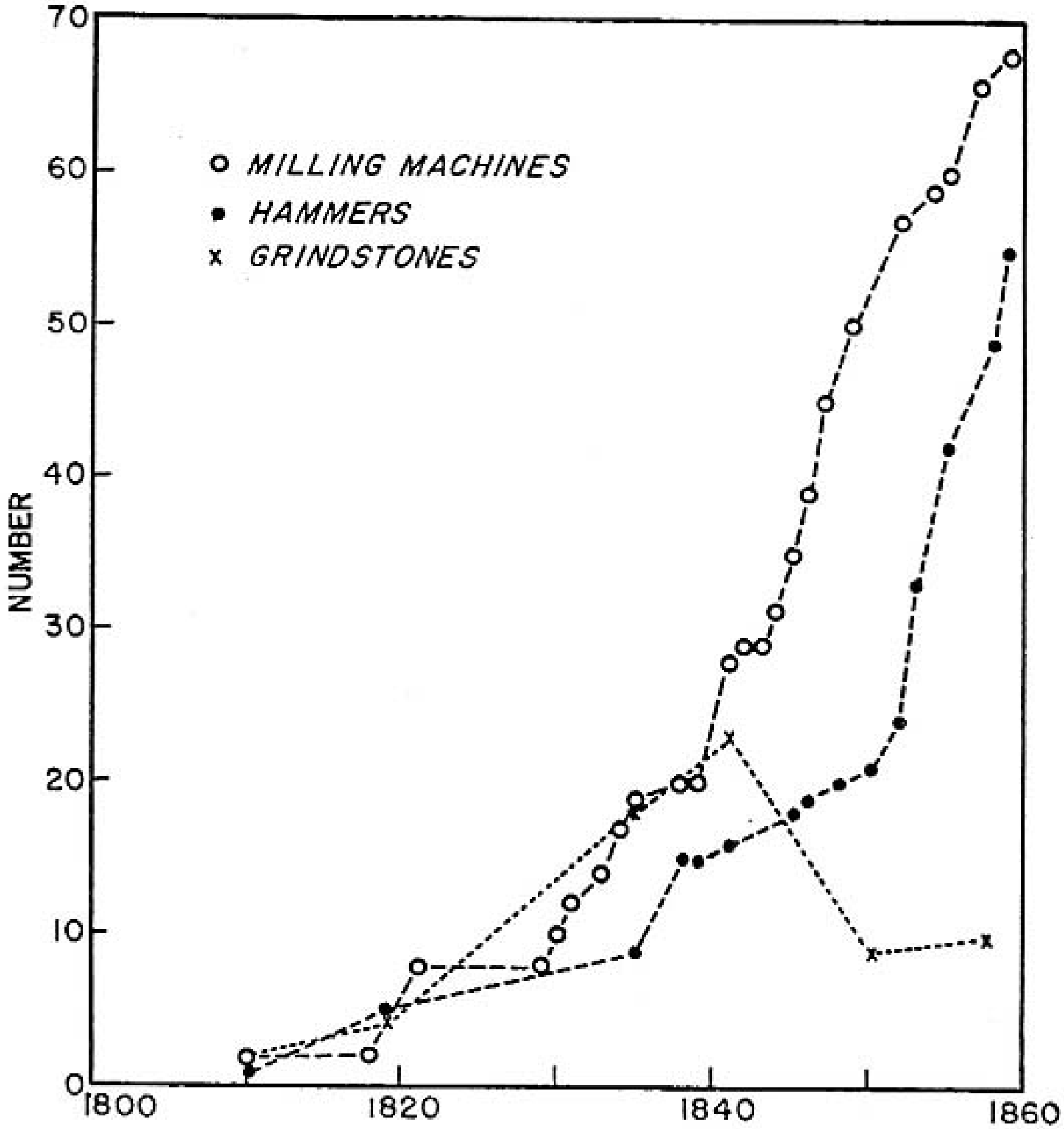

Figure 7.1. PIECES OF SELECTED MACHINERY AT SPRINGFIELD ARMORY, 1810-1860

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880 ARSA 1845-60; Anonymous, Marco Paul's Adventures . .

F. Mechanized Metalworking and Stocking during the Civil War

Metalworking

We have two sources of information about the machinery in use at the Armory after the expansion to wartime production. One is the "Statement of Machines and Manufacturing Capacity at Springfield Arsenal" for January 1, 1864;[881] Table 7.9 is based on these data. The other source is a list of the machinery required for an armory to make 500 rifle-muskets per day of 10 hours prepared by the Superintendent, Alexander Dyer, at Springfield about the same time in 1864;[882] which is the basis for Table 7.10. Since Springfield was producing about 900 rifle-muskets per day in 1864 by working two shifts, the latter list should show very nearly the machinery actually in use at the height of war-time production. There are some discrepancies between the lists that suggest that they may have been hurriedly drawn up. For example, both lists specify 34 rifling machines, but while the inventory includes 36 trip hammers and 74 barrel boring machines, Dyer's list calls for 51 and 37 of these machines, respectively. We will assume that the inventory (Table 7.9) is the more accurate representation of the machinery actually in use.

A comparison of Tables 7.7 and 7.9 show that there was a very large increase in the number of machine tools at the Armory between 1851 and 1864. There is little doubt that the ability of the Armory to acquire this machinery was a significant factor in enabling it to achieve its record levels of production during the war. To see the change in the intensity of machine use from these data, allowance should be made for the increase of the rate of production from about 500 muskets per week in 1850 (including an allowance for muskets converted from flint to percussion) to 3600 per 60-hour week in 1864, an increase by a factor of 7.2. Stocking machines increased in number by only 2.4 times while the number of millers increased by 5 times. Thus, either the machines in use in 1864 had a much larger production capability than those used in 1850, or the machines present in 1850 were not working to full capacity.

Another change between the lists for 1851 and 1864 is that more machines are listed as intended for specific tasks, such as the machines for tapping barrels, for milling and threading breech screws, and

[881] Microfilmed Springfield Armory Records, Miscellaneous Volumes, Microfilm Reel #233, SANHS.
[882] Dyer to Ramsay, February 4, 1854.

the bayonet socket lathes. Large grindstones were no longer in use in 1864. We infer that Springfield was still building many of its own machine tools, since there would be no direct work for the 29 power planers or the gear cutters listed in Table 7.9 in making small arms.

The data in Table 7.1 show that between 1860 and 1864 the proportion of labor devoted to forging decreased from 15% to 5% and thereafter remained low. We ascribe this to new mechanization of the forging process. According to Fitch, Harvey Waters of Millbury demonstrated in 1861 how to forge bayonets by rolling them in chilled iron rolls rather than under a trip hammer. This technology was adopted at Springfield, where a roll with nine grooves was used for the purpose. Fitch also stated that 10 drop hammers were built for Springfield in 1861 by Lamson, Goodnow & Yale of Windsor, Vermont, to replace some earlier models that were "of a rough character."[883] Table 7.9 shows that by 1864 drop hammers, which are used for closed die forging, had become more numerous than trip hammers. This investment in drop hammers substantially reduced the labor that had to be devoted to forging components before they were machined and filed to finished form.

Two new machining techniques appeared between 1860 and 1864. The most important was profiling, by then the fourth most numerous type of metal cutting machine. Profiling first appears on the work returns at this time as well (see Table 7.1), although it represents only 1% of the total labor. A practical profiling machine was designed by F. W. Hawe for Robbins & Lawrence in 1848, and is reported to have been used at Springfield in 1849.[884] The payroll records, however, show that only very limited use was made of this technology before 1864. The other new technique was broaching, which was used on the middle and upper bands.[885] Otherwise, the increased production during the War was accomplished by expanding the use of existing methods and techniques, as shown by the small changes in the distribution of labor between different tasks (Table 7.1).

Dyer described each operation used to make the parts of the rifle-musket, showing the amount of hand and machine work done. The data for the tumbler are summarized in Table 7.11. The machinery used to make this part cost $3,950 and the total labor cost for 500 tumblers was $53.08.

[883] Fitch, pp. 20-21.

[884] Fitch, pp. 27-8.

[885] Prescott.

The actual operations carried out by the different machines are not specified, but the first milling was probably hollow milling of the arbor and pivot, and the second and third milling probably the shaping of the perimeter of the tumbler. Filing was required to bring these dimensions to gage. The distribution of hours (and costs) is 7% (6%) for forging, 41% (45%) for machining, and 52% (49%) for filing. Thus, despite the use of eleven different types of machine tools in making the tumbler, filing remained the largest expense and represented the greatest number of hour of labor in its manufacture. It also demanded the highest grade of labor.

Stock-making

Cyrus Buckland's second-generation machines lasted a long time. As indicated in Tables 7.10 and 7.11, Armory reports during and after the Civil War show the same basic types of stocking machines as in the 1850s, with the addition of the already-mentioned machine for boring the closed channel for the ramrod, and one for shaping the ends of butts, which appeared in the 1864 lists and disappeared by mid-1872. The estimated prices for the stocking machines in 1864 ranged from a low of $150 for a "centering" machine (used in preparing the stock for subsequent lathes) to a high of $2,550 for a lock-bedding machine.[886] The Armory had to increase its number of stocking machines in order to expand its output during the war. By this time, outside machine-tool companies had grown up that were able to produce several kinds of stocking machines; the Armory did not have to build its own.[887]

Since the different machines took different amounts of time to complete their operations, a smoothly-running production line would need more of some kinds and fewer of others. In Superintendent Dyer's January, 1864 statement of the machines, tools, and men that would be required to stock 500 rifle-muskets in ten hours, one can find the proportions that would be needed for a balanced production line for that level of output. For instance, two men operating one machine each to bore the closed ramrod channels were required to keep up with one man operating a single machine to cut the open ramrod grooves. Twice as many (four) lathes for rough-turning the

[886] Dyer to Ramsay, February 4, 1864.

[887] Besides Ames Manufacturing Company of Chicopee, Mass., who had made the stocking machines for Enfield Armoury in England, makers of stocking machines in the Civil War potentially included any makers of Blanchard lathes for other purposes, such as the hat-block machines of Gilman and Townsend in Springfield, Vermont. The Ames Company had a long-standing relationship with the Armory.

butt were needed as for rough-turning the tip of the stock (two), but one man could operate two of the butt-turning lathes at a time, so only four "ordinary wood workmen" in all were required for rough-turning. Since they ran more slowly, twice as many (twelve) lathes were needed for finish-turning as for rough-turning (six), but only two "first-class wood workmen" were required to tend all twelve. Similarly, twice as many men and machines (two each) were needed for lock-bedding as for guard-bedding (one each). As mentioned previously, the greatest need for men was still to do hand-tool work in three "fitting" operations and in "completing" the stocks: 68 men are so designated in Dyer's hypothetical list out of a total of 93.[888]

Table 7.9

MACHINERY AT THE SPRINGFIELD ARMORY ON 1 JANUARY 1864[889]

Forging:

36 Trip hammers, 75 lbs average	2 Rolls for bending sheet iron
43 Drop hammers, 300 lbs average	5 Rolls for barrels
126 Smith's forges	13 Rolls for drawing iron setts
2 Rolls for curving scalps	12 Fan blowers, 5 psi

Metal machining:

34 Rifling machines	2 Machines for tapping barrels
35 Hand lathes, fixed rest	4 Bayonet socket lathes
2 Broaching machines	1 Sticking machine
1 Stamping lock plates	1 Shaving machine
53 Profiling machines	2 Horizontal drills
50 Drilling and boring machines	74 Barrel boring machines
3 Bayonet boring machines	11 Cone machines
7 Bayonet polishing machines	3 Barrel staighteners
8 Barrel polishing machines	2 Ramrod polishers
25 Barrel and breech turning lathes	
282 Milling machines for components	
7 Hand planers 15" wide x 12" high x 24" long	
29 Power planers, lengths 3 to 14', various heights and widths	
2 Machines for cutting threads on butt and guard screws	
- Machines for milling and threading breech screws (unknown number)	
3 Plain slotting machines, average 8 1/2" length of cut	
1 Punch, will make 3" hole in 5/8" iron plate	

[888] Dyer to Ramsay, February 4, 1864.

[889] “Statement of Machines and Manufacturing Capacity at Springfield Arsenal" for January 1, 1864.

20 Punches, will make 2" hole in 1/2" iron plate
1 Screw cutting machine 2" diameter by 20' long
5 Screw cutting machines, 0.2 to 1" diameter by 6' long
13 Slide rest lathes for turning only, 2" diameter, 2'6" long
67 Slide rest lathes for cutting screws, 2" diameter, 2'6" long
24 Slide rest lathes, double geared, 3" diameter, 4' long

Stocking:

14 First and second turning	1 Turning between bands
2 Bedding butt plates	4 Barrel bedding
3 Boring stock for ramrod	2 Guard bedding
1 Grooving for ramrod	2 Lock bedding
2 Sawing and facing	2 Sawing and shaping butts
1 Turning on bands	

Other:

10 Circular saws, 10"	1 Vertical saw, 12" stroke
2 Cutting arms chests	2 Centering machines (wood)
2 Boring for arms chests	4 Force pumps
1 Spotting machines (wood)	2 Universal gear cutting machines

12 Grinding machines for plane surfaces
1 Planing machine 24" wide x 4" high x 144" long (for wood)
2 Planing machines 24" wide x 18" high x 336" long (for wood)
1 Double-geared threading machine for gas pipes

Machines on hand and on order are listed separately in the "Statement" but are combined in this table.

Table 7.10

SPRINGFIELD ARMORY PRODUCTION MACHINERY IN 1863 AND 1872[890]

Forging:

57 Drop hammers, 30/23	5 Barrel rolls (sets) 1/4
51 Trip hammers 11/26	1 Curving scalps 0/2

Metal Machining:

225 Milling machines 199/89	3 Barrel straightening 1/2
53 Drill presses 43/23	3 Rotary filing 0/0

[890] Dyer to Ramsay, February 4, 1864; Armory inventory for 1 July 1872.

37 Barrel boring 14/64
35 Profiling 40/19
34 Rifling 8/32
26 Turning lathes 57/23?
24 Barrel & breech lathes 19/12
29 Power presses 30/8
13 Grindstones 0/0
6 Barrel polishing 4/4
5 Screw presses (hand) 5/0
5 Slitting 3/2
3 Broaching 1/3
3 Bayonet boring 2/3
1 Cutting butt & guard screws 1/0
2 Centering 1/1
2 Cone drilling 0/10
2 Ramrod polishing 2/1
2 Tapping, barrels 2/1
1 Checking hammers 0/0
1 Counterboring sights 0/0
1 Milling & threading 2/2
1 Reaming bayonets 0/0
1 Stamping lock plate 1/0
1 Shaving bridles 0/1
1 Slitting & burring 3/2
1 Qualifying 0/0

Stocking:
16 Stock lathes 10/7
3 Barrel bedding 1/3
2 Lock bedding ½
1 Bedding butt plate 1/1
1 Guard bedding 2/0
1 Turning between bands 1/0
1 Guard bedding 2/0
1 Groove for ramrod 1/1
1 Spotting stocks 0/3
1 Shaping for butt plate 0/0
1 Turning for bands 1/1

Numbers after each entry are the number of machines in use and the number on hand but not in use in 1872. For example, 30 of 53 drop hammers were in use in 1872.

Table 7.11

OPERATION IN MAKING A TUMBLER IN 1863[891]

A	B	C	D	E	F
Block	1 Trip hammer	$400	10	0.00375	Ordinary b'smith
Drop swage	1 Drop hammer	600	5	0.0025	Ordinary b'smith
Anneal				Day labor	
Trim	1 Power press	600	1	0.0005	
*1st mill	3 Millers (small)	300	20	0.0085	Ordinary mech.
Drill	1 drill press	200	10	0.0044	Ordinary mech.
2nd mill	2 Millers (large)	400	10	0.0056	Ordinary mech.
Free	1 Miller (small)	300	10	0.004	Ordinary mech.
3rd mill	4 Millers (large)	350	20	0.011	Ordinary mech.
Slit	1 Tumbler slitter	300	8	0.004	Ordinary mech.
Square	1 Miller (small)	300	10	0.005	Ordinary mech.
Contersink	1 Drill press	200	3.5	0.0034	Ordinary mech.
Crown pivot	(same as countersink)		2	0.0015	Ordinary mech.

[891] Dyer to Ramsay, February 4, 1864.

1st tapped	(Bench work)	2.5	0.002	First class mech.
File	(Bench work)	120	0.052	First class mech.
2nd tap	(Bench work)	3	0.0017	First class mech.
Temper			Day labor	
Finish	(Bench work)	5	0.003	Good mech.

Column headings: A Operation
B Tool used and number required to make 500 parts in 10 hrs
C Cost of individual tool
D Man hours required to make 500 parts
E Piece rate
F Class of artificer required

G. Armory Mechanization, c1865-1892

The end of the Civil War left the Armory with a large stock of machine tools, which made up the principal equipment of the Armory for many years afterwards. The data in Table 7.9 show that many of these machines were not in use in 1872. A few, the cone drills and the machine for curving scalps, were by then obsolete since the Armory was making breechloading rifles with steel barrels. Springfield Armory rarely had enough funds for substantial purchases in this period for up-to-date machine tools.[892] After the development of the trapdoor design, the form of the service muskets and carbines changed very little, and the Armory could make do without a lot of new manufacturing equipment.

One change in the manufacturing technology for making lock parts, introduced by c1872, was the replacement of hollow milling the arbor and pivot by clamp milling. Our examination of locks on Springfield arms at the Armory Museum shows that a better surface finish was obtained with this technique.[893] However, many of the machining operations remained the same until the bolt action rifle was put into production after 1892, and many of the machines were not highly specialized and could be adapted to new requirements, as discussed in the following pages. We note that the relative

[892] See Hugh G. H. Aitken, Scientific Management in Action: Taylorism at Watertown Arsenal, pp. 51-52; Edward C. Ezell, "The Search for a Lightweight Rifle: The M14 and M16 Rifles," Fred H. Colvin, 60 Years with Men and Machines, p.184; Fred H. Colvin and Ethan Viall, Manufacture of the Model 1903 Springfield Service Rifle, p. 95; and National Archives, Record Group 156/1382, Springfield Armory contracts.

[893] Robert B. Gordon, "Material Evidence of the Manufacturing Methods Used in `Armory Practice.'"

number of profiling machines in use in 1872 was substantially larger than in 1864; this is mirrored by the data in Table 7.1, which shows that profiling became an increasingly important of the total labor in making a rifle throughout the rest of the 19th century. In these years filing became relatively less important, which we interpret as evidence of improved machining technology that allowed parts to be brought closer to final dimensions before they were finally finished to gage with the file.

The decrease in the labor spent on rolling and welding between 1864 and 1878 can be ascribed to the replacement of welded iron barrels by drilled steel ones. The steel barrel was adopted for the M1873. A 3/4-inch hole was drilled longitudinally through a steel bar two inches in diameter by 9.25 inches long. The drilled bar was heated, placed over a mandrel, and passed through grooved rolls. The rolls drew the tube over the mandrel, and passage through a sequence of eight grooves brought the steel tube to the shape and 32.6-inch length of the barrel. The rolling process was essentially the same as that introduced at Springfield for wrought iron barrels in 1859.[894]

The Armory adopted a new metalworking technique, cold pressing, in 1875.[895] By pressing between precision dies, parts were brought closer to their final dimensions than was possible in forging hot metal. Both mechanical and hydraulic presses were used. The high cost of the powerful presses required for cold pressing limited the general application of this technique in arms making, and it did not figure significantly in the distribution of labor at the Armory.

The additional stocking machines that were laid on during the Civil War were too many for the post-war level of production to which the Armory receded by mid-1872, so some were kept in inventory, but not used. For instance, at the time Dyer wrote that a total of 18 stocking lathes would be needed to produce 500 rifle muskets a day, he had 14 on hand or on order. By July, 1872, there were 17 on hand, but only ten in use. All told, while 34 stocking machines were on hand or on order at the beginning of 1864, by mid-1872 there were 37 on hand, but only 18 in use (Tables 7.10 and 7.11).

The basic design of the Blanchard-Buckland machines allowed for easy adaptation to changes in the model gun under production. Within reasonable size limits, a change could be effected just by

[894] U.S., Ordnance Department, Fabrication of Small Arms for the United States Service.

[895] Fitch, p. 12.

changing the relevant irregular solid or hollow "formers" that the machines copied, instead of having to design a whole new machine for each operation. Even though the standard issue weapon finally changed from muzzle- to breech-loading in the 1870s, the stocks were not radically different. Hence the machines and hand-tool processes of stocking listed in the payroll and described by James G. Benton in 1878 were still identifiable with those of the mid-1850s, with the addition of one machine for "cutting out the sides and bottom of the lower end of the groove... and cutting the groove for the arm of the hinge-pin." These cuts were to accommodate the receiver on the newer, breech-loading model.[896] Of the stocking process around this time, Fitch wrote that the "...last few hand operations require about five-eighths of the labor...all the varied and curious cuts made by machinery requiring only three-eighths."[897]

H. Mechanization and the Manufacture of Bolt Action Rifles, 1892-1917

The Challenge of the Krag

In 1892, the Ordnance Department gave the Armory a major technical challenge: Springfield was ordered to make its first magazine-loading weapon for general service use. The bolt-action Krag-Jorgensen Rifle, which American troops would soon call the "Krag," was a complicated mechanism requiring a high degree of manufacturing sophistication. The new design, and the new metallurgical requirements imposed by the introduction of smokeless powder cartridges, made the change in production particularly difficult for the Armory. In order to mass produce this weapon, Armory engineers and tool-makers relied heavily on older types of machine tools, often adapting them for operations on completely new parts.

The process of "tooling up" to make the new weapon involved major reorganizations of Armory production machinery and administration (Chapter 6). Armory managers eventually counted 1318 separate operations in the manufacture of the Krag. Although methods of defining a single operation changed over time, it is apparent from earlier descriptions of the manufacture of the Model 1873

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[896] Springfield Armory payroll, Jan. 1878; Benton, p. 113. Benton's Plates V, IX, XI, XV, and XXVII show stocking machines virtually identical to those in the 1859 Engineer, cited above, except that the workpiece and "former" in the Blanchard lathe are arranged side-by-side in 1859 and one above the other in 1878 (P1. XV).

[897] Fitch, p. 629.

"Trapdoor" rifle that more machine operations were involved in making the Krag.[898] The fact that many important components of the repeating rifle were particularly difficult to produce proved critical in the tooling up process. Col. Alfred Mordecai was under great pressure from the Chief of Ordnance to produce the new rifle quickly when he took command of the Armory in 1892. Hoping to speed operations and lower costs, Mordecai tried to attain interchangeability of parts in this "new and more complicated arm" with greater use of special-purpose machining operations, and with much less hand-filing than had previously been the case.[899]

The Armory was already being expanded, and it was Mordecai's responsibility to integrate new and old machinery into an effective manufacturing system. He had to build on the existing stock of machine tools, and improve the manufacturing capability of his various shops. He could draw on the vast experience of his master armorer, shop foremen, draftsmen, inspectors, toolmakers, and machinists. He also tried to move away from what he believed were costly and inefficient practices of the past, among which he included hand-filing parts to gage, and having experienced machine operators spend too much time on burr removal and the transfer of parts back and forth to inspection rooms. The commanding officer thought lower-paid boys and young men could do the latter tasks and that better machining operations could eliminate the first.[900]

Although Mordecai and his armorers made many improvements to the production system in making the Krag, the Armory's greatest mechanistic achievements in the period between 1892 and the First World War were in what Fred Colvin called the "little kinks and devices,"[901] the innovative jigs, fixtures, cutting tools, and gages that turned basic machines into special-purpose components of a highly-effective production system. Creating such systems had been a particular Armory strength since, probably, the mid-1830s, although there is little documentation of Armory jig and fixture use before the Krag era. As discussed in the following pages, Mordecai tended to underestimate both the

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[898] ARCO 1896, p. 55. For information on the adoption of the Krag, see Lt. Col. William S. Brophy, The Krag Rifle; Ludwig Olson, "The Krag Rifle," pp. 47-52; and E. J. Hoffschmidt, "U. S. Krag," pp. 34-35.

[899] ARCO 1893, pp. 200-201; ARCO 1894, pp. 52-53; Mordecai to Chief of Ordnance, Jan. 14, 1893, RG 156/1354.

[900] Flagler to Mordecai, February 8, 1893, RG 156/1365; ARCO 1894, p. 53; editorials and letters to the editor, American Machinist (March 3, 1898) p. 170, (March 24, 1898), p. 219, (April, 21, 1898), pp. 293-294.

[901] Colvin and Viall, p. 13.

importance of Armory employees in devising mechanical solutions to new rifle designs, and the persistence of handwork required to meet Armory standards of interchangeability. Springfield's enormous reservoir of mechanical skills allowed traditional Armory approaches to triumph over rifle designs unlike anything made there before. Magazine rifle production thus represented more a perfection of an older system than the introduction of radically different approaches to manufacture. Traditional standards of interchangeability imposed costs in productivity, however, which Armory managers tried to address with faster equipment in the early 20th century.

Planning Early Krag Production

Until his death in June 1894, Master Armorer Samuel W. Porter played the most important role in setting up the first production system for the new rifle. Porter studied each piece of the weapon, "and drew up a scheme of the operations and the order in which they should be taken to construct each piece." His schemes were the basis for general drawings of the fixture or fixtures required for each machine involved in an operation. "Mechanical draftsmen" produced those drawings, but "in order to make use of machinists of different grades, the general drawings of fixtures were dissected by draftsmen of a lower grade and drawings made of the parts in detail." As the planning of operations and the evaluation of rifle parts and machine fixtures continued, it was "found necessary to modify the schemes as first drawn." Mordecai's busy staff also had to design cutters for use with the fixtures and gages for checking the progress and successful completion of the work. Actual testing of fixtures and cutters on the machine tools was an essential step, and here the Armory's shop foremen and machinists must have been heavily involved. It was necessary "to determine whether or not the work required can be properly accomplished." When Mordecai submitted his annual report in the summer of 1893, work was still underway on fixtures. Plans called for a total of 537 fixtures, including 35 for the separate bayonet. Only 449 had been required for the last model of the Trapdoor Springfield Rifle (Model 1888) which had an integral rod bayonet.[902]

The progress of Samuel W. Porter and his subordinates did not satisfy the Ordnance Department's insistence that the new rifle move into production rapidly. As discussed in Chapter 6, Mordecai made some heavy-handed attempts at organizational reform after Porter's death. In addition to

[902] ARCO 1893, pp. 200-201. The "fixtures" included jigs, which had many applications at the Armory. There were 88 parts in the new rifle and bayonet compared with 84 in the old model. The new rifle was, however, much more difficult to make. For distinctions between rifle models, the standard source is Norm Flayderman, Flayderman's Guide to Antique American Firearms.

controlling foremen more closely with his officers, Mordecai replaced some senior employees who did not measure up to his standards (or, perhaps, who did not agree with the new procedures), and converted many jobs to simple, repetitive operations. He could not, of course, rely on officers and administrative demands to appease the chief of ordnance. To replace the master armorer's role in coordinating changes in methods among the various shops, Mordecai had to establish a committee of one officer and the foremen of the milling, forging and finishing, and filing shops. This committee, which functioned from December 1894 to at least August 1897, was instrumental in determining machining operations needed for each metal rifle component, and in classifying the grades of skill needed for each operation. Piece rates, virtually suspended during the tooling up process, were gradually re-established based on the committee's work.[903]

Mechanical Adaptations for the Krag

Stock-making

The design of the Krag required a stock sufficiently changed from the traditional stock that several new types of machine for stocking entered the gunstock production line, while others remained the usual Blanchard-Buckland machines, presumably retooled with formers of changed shape. The stock-turning lathes were unchanged in design from those of 1878.[904] But some old machines were discontinued: for instance, for the first time since Blanchard's day, no lock-bedding machine was in operation.[905]

To accommodate the metal parts of the Krag, the stock had to be excavated much more extensively from the top than had been the case in former models of muskets and rifles at Springfield. Thus a machine for "slotting the stock," pictured in the Scientific American in 1899, was inserted into the production sequence between the rough turning of the stock and the bedding of the barrel and receiver.[906] The machine for doing the latter two operations, however, was the same as the old

[903] Springfield Armory Post Orders, No. 63, December 18, 1894, and No. 32, August 19, 1897, SANHS; ARSA 1895, in ARCO 1895, pp. 66-7.

[904] Cf. picture in Scientific American, "Manufacture of Krag-Jorgensen Rifles at the Springfield Armory--I," p. 267, with Plate XV in Fabrication of Small Arms for the United States Service.

[905] Springfield Armory payroll, January 1898; plan labelled "2[nd] Floor of Stocking Shop. Location of Machines Scale 1/8"--1'. Springfield Armory, July 19, 1899," SANHS.

[906] Scientific American, "Manufacture of Krag-Jorgensen Rifles at the Springfield Armory--II," picture p. 330, text 331.

second-generation barrel-bedding machine, which had three vertical-spindle cutters in the 1850s and four in the 1878 version; this one had six vertical-spindle cutters in addition to its usual two horizontal-spindle cutters.[907] But a floor plan of machine placements at the stocking shop that year also indicates extra machines for coping with the receiver: a receiver-cutting machine and a receiver-bedding machine in addition to the three barrel-grooving machines.[908]

Compared to the ideal 500-gun-a-day stocking operation described 35 years earlier, the 1899 stocking shop was the same in its proportion of machines for rough turning the butt and tip sections of the rifle, but smaller in scale, with two instead of four for butt- and one instead of two for tip-turning, as had been recommended for an output of 500 stocks a day. Yet it had the same number (three) barrel-grooving machines, perhaps because their task was larger than before.[909]

Because of design changes in the stock and bayonet, the stocking shop producing Krags in 1899 also included three new machines for turning, cutting off, and grooving hand guards to lie on top of the barrels and two for turning and cutting off bayonet grips for the saber-style bayonets. It no longer used the Civil War machines for making ramrod grooves and holes, but instead had three for boring holes in which to stow various other items in the stock: one for holes for the segmented cleaning rod, another for unidentified holes in the butt, and yet another for holes for small oil cans.[910]

Woodworking has always created shavings, chips, and sawdust. Many of Buckland's second-generation stocking machines were outfitted with fans forcing air through curved pipes for continuous blowing of wood debris away from the cutting action. In the stocking shop of 1899 the Armory tackled the larger problem of removing it from the room altogether by way of a system of exhaust pipes leading from above each machine.[911] In 1911 the Armory addressed the next step of

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[907] Ibid., picture cover page, text p. 331.

[908] Plan labelled "2[nd] Floor of Stocking Shop. Location of Machines Scale 1/8"--1'. Springfield Armory, July 19, 1899," SANHS.

[909] Ibid.

[910] Ibid.

[911] Ibid.

automating the task of chip disposal: it proposed "to install a hopper on the roof of the boiler house to receive the chips from the exhaust of the woodworking shops and feed them automatically into the furnaces."[912]

Besides the machines, in the stocking shop of 1899 space was allowed at the other end for 18 benches for stockers. We infer that this was for the remaining non-machine work on the stocks—smoothing, oiling, etc.,--and, in the absence of sanding machines, that this still comprised a substantial amount of the total work time.

Metalworking Machinery and New "Kinks and Devices"

Metalworking for the Krag required far more extensive changes than stocking. Although the Armory did purchase a number of new machines as part of the expansion and modernization effort of the early 1890s, major additions of machinery had to wait until the Spanish-American War showed the government that a much higher production rate was necessary.[913] When making purchases, officers selected machines that usually required specially-designed fixtures and cutting tools to prepare them for the particular production tasks at the Armory. Scientific American said in 1899 that the Armory "manufactures all its own tools and designs, and makes the many improvements which are added from time to time in its purchased machines."[914]

Builders of both general and special purpose machine tools sold equipment to the Armory in the late nineteenth century. The Pratt & Whitney Company, in particular, offered machines of great value to arms manufacturers. Of the 28 rifling machines which cut spiral grooves in the bores of Krag rifle barrels in 1899, ten were new Pratt & Whitney machines. The other eighteen were "machines of an old type that have been in the shops for about forty years." Barrel drilling, which had been introduced for the Model 1873, was a greater challenge with the adoption of the smaller caliber Krag. Again, the Armory turned to Pratt & Whitney, purchasing an "ingenious machine" that could drill a barrel after it had been rolled. The .30” caliber bore was not suitable for the former process of rolling and thereby lengthening a short, drilled bar. Now a machine operator had to drill a hole

[912] ARSA 1911, p. 5.
[913] ARCO 1898, p. 87.

[914] "Manufacture of Krag-Jorgensen Rifles at the Springfield Armory - II," p. 330.

through a rolled steel piece over thirty inches in length. This drilling machine included a means of delivering oil under pressure for cooling purposes and for flushing out chips. As was often the case, an Armory employee significantly improved the operation of the machine with a small modification. Maj. D. M. Taylor received credit for replacing the former oil channel along the side of the drill with a hole running directly to the point. This improvement may or may not have been entirely Taylor's idea, but it was developed within the Armory.[915]

Most machining operations on the new rifle, as on the older breechloading rifle-muskets, were forms of milling. Colvin, an editor of American Machinist, commented in 1916 on the fact that gun making shops were "more plentifully supplied with millers than lathes."[916] The Armory in the 1890s still depended primarily on two early types of milling machines: the hand miller, which had no power feed for moving the workpiece and the Lincoln miller, which had a power feed (although in the Armory production system, this feed was sometimes replaced by a manual one).

For making the often complex shapes of firearms, toolmakers at the Armory used large numbers of formed milling cutters and often linked multiple cutters in "gangs" on a single arbor, or rotating shaft.[917] They also used profiling machines, which used templates to guide single milling cutters. The Armory, as we have seen, had a metal profiling machine by 1849 and made considerable use of them by 1864. The Ames Manufacturing Company in nearby Chicopee was an important producer of these machines. Colonel Mordecai preferred to keep these profiling operations to a minimum because they required the most skilled and highest paid machine operators and because they were relatively slow to complete.[918] Profiling was also expensive because the machines were more than twice the price of Lincoln millers.[919]

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[915] "Manufacture of Krag-Jorgensen Rifles at the Springfield Armory - I," pp. 267-268; "Manufacture of Krag - II" pp. 330; Nathan Rosenberg, Perspectives on Technology, pp.25, 30; Contract with Pratt & Whitney Co., 13 May, 1896, RG 156/1382; ARCO 1898, p. 87.

[916] Colvin and Viall, p. 101.

[917] "Manufacture of Krag-II," cover and p. 330.

[918] ARCO 1895, p. 67. Profiling had the highest minimum pay level at $2.00 per day. Some milling operations paid as little as $1.00 per day (piecework estimates were used), but in all cases the highest pay level was determined to be $2.50 per day (polishing, milling, drilling, and filing).

[919] Proposal of January 10, 1902, RG 156/1382.

Mordecai claimed in 1895 that "Some very ingenious fixtures have been planned, made, and put into operation. These were mainly to avoid the use of profiling cuts." He was referring here to milling fixtures, the most common type, although fixtures were also important in other operations. Jigs and fixtures, as we have seen, were always important in the manufacture of interchangeable parts. Combined with special cutting tools, they transformed most of the Armory's basic, and often out-dated, machine tools into special-purpose machines. They could also multiply the production rate of a machine and its operator by reducing the time for an operation or by alluding cuts on more than one part at the same time.[920]

A fixture holds a workpiece (or workpieces) and positions it for a machining or gaging operation. It must be securely attached to a machine when in use, while a jig might only be attached to the workpiece. The important distinction is that a jig, unlike a fixture, actually guides cutting tools in their action on a workpiece. It is most often used in drilling operations, hence the common term "drilling jig." Since the 19th century, many machinists have used the terms jig and fixture almost interchangeably; indeed, some devices described in this study did have characteristics of each.[921] Franklin D. Jones, in his 1920 book on Jig and Fixture Design, said that "Jigs and fixtures may be defined as devices used in the manufacture of duplicate parts of machines and intended to make possible interchangeable work at a reduced cost, compared with the cost of producing each machine detail individually." He argued that these devices allowed the use of a "much cheaper class of labor" and were particularly valuable in the production of large numbers of parts which had to be either "alike" or "perfectly alike."[922]

Incremental Innovation on the Shop Floor

Jones argued that properly designed jigs and fixtures made sure that the work was located correctly and that the machining operation was done in the same way for each piece. Much time was saved through efficient clamping devices, and a good fixture also helped to prevent spoiled work.

[920] ARCO 1895, p. 67; and F. D. Jones, Jig and Fixture Design, pp. 3-6, 9-11, 211. We are indebted to Matthew Roth for information on the terminology of jigs and fixtures.

[921] Colvin and Viall, p. 13; Franklin D. Jones, Jig and Fixture Design, pp. 36, 9-11, 211.

[922] Jones, pp. 1-2.

Although Jones acknowledged that "many object to the term 'fool-proof,'" he did use this pejorative expression when discussing the goals of jig and fixture design. Like the ordnance officers at Springfield in the 1890s, Jones wanted to reduce the need for skilled machinists on production jobs to a minimum. Neither he nor they gave sufficient credit to talented machine operators who often came up with ideas for improving the jigs, fixtures, and tools they used. Colonel Mordecai, in resisting a former worker's financial claims for improvements during his years of employment, stressed that "Workmen constantly adopt little devices to facilitate their work" and that no special reward for this normal practice was required.[923]

Colonel Mordecai reluctantly acknowledged that incremental innovations on the shop floor were common. Men charged with the continual operation of a machine, or a fixture, were in a good position to observe its faults and had time to think about possible improvements. It is finally becoming apparent to historians that important changes in manufacturing often take place gradually as the result of many small improvements.[924] At the 19th-century Armory, credit for such innovations frequently went to military officers, some of whom were unquestionably men with considerable mechanical talent. One has to wonder, however, if some of the designs from managers were not based on suggestions from the shop floor. In the first two decades of the 20th century, most officers were no longer spending enough time in their Armory posts to learn the technology of small arms production, a serious deficiency identified by commanding officers in several reports to the Chief of Ordnance.[925]

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[923] Jones, pp. 1-2, 5-6, 211, 288; Mordecai to Chief of Ordnance, March 26, 1892, RG 156/1354. Edwin Battison has told author Malone that the Armory's expansion of the piece rate pay system, mentioned above, would probably be a strong stimulus for increased innovation on the shop floor. Another stimulus, common in many progressive factories today, is a program of financial rewards. As we see here, the Armory was reluctant to give such rewards.

[924] One of the greatest weaknesses in the written history of manufacturing technology has been its tendency to focus on major machine and system innovations and to ignore the incremental changes that may be, in their "cumulative effect", even more important. For a brief discussion of the effect of these "relatively small innovations" and the problem of "Schumpeterian blight," see Rosenberg, Perspectives, p. 292.

[925] ARSA 1907, p. 3; ARSA 1917 p. 6; ARSA 1918, p. 11, all SANHS. The problems caused by inexperience and short tours of duty were aggravated by the fact that officers were needed most "in a managerial capacity," and the Armory could not afford to give them time to study manufacturing technology. During World War I, the number of assistant officers at the Armory was so limited that none were able to take "the course of practical instruction in the manufacture of the rifle." Some of the letter writers and editors whose comments appeared in American Machinist in 1898 were critical of the whole concept of putting military officers in charge of manufacturing at the Armory. The most "cutting" attack used an interesting analogy: "If we want a jack-knife made we don't go to the man who has had experience only in using jack-knives." See "Army Officers versus Civilians as Superintendents of Armories," American Machinist (April 21, 1898), pp. 293-294.

In 1917, an article titled "Helping the Foreman to Get Results" appeared in American Machinist. It pointed out facts that were probably obvious to most of the journal's readers: "...many good ideas are gathered from the rank and file and it is to the foreman's best interests to bring out the best that is in his men." The author urged shop foremen to "accept the best and use it to the shop's betterment." Surely the successful foremen at Springfield had always followed this practice; most of them had risen from the rank and file in the production shops or had served an apprenticeship under a skilled machinist. "Shop culture," still a powerful influence on mechanical engineering in this period, promoted the educational value of actual experience in machine operation and encouraged respect for the ideas of "practical men."[926]

A machine operator or a tool-maker at Springfield might suggest innovations for any number of reasons. Personal and institutional pride was likely factors, as was the satisfaction that comes from a successful technical solution. Patriotism must also be considered in an armory that supplied weapons for the nation's fighting men. Innovation could also be a way to get ahead in pay, professional status, or both. An operator might hope that a technical change in the machinery that he ran on a piece-work basis would increase his productivity and therefore his take-home pay. Of course managers could always reduce piece-work rates if they saw a sharp increase in productivity, but the chance for at least a temporary financial gain was rea1.[927]

There was no program of cash rewards for suggestions by Ordnance Department employees until 1912, and then the payments were so low that workers were no longer applying for the tiny sums in 1914. A published justification for starting the program provides evidence that workers' ideas had proven to be valuable: "The history of this department contains many instances of suggestions by

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[926] George Sawitzke, "Helping the Foreman to Get Results," (August 2, 1917), p. 196. Sawitzke was the superintendent of the Osborn Manufacturing Company. For discussion of advancement from the shop floor and of the value of shop experience for draftsmen and designers, see Donald A. Baker, "Technical vs. Practical Tool Designers," (December 13, 1917), pp. 1037-1038. Examinations of shop culture are in Monte Calvert, The Mechanical Engineer in America, 1830-1910 and in Daniel Nelson, Managers and Workers: Origins of the New Factory System in the United States, 1880--1920.

[927] Baker, "..Tool Designers," pp. 1037-1038. Edwin Battison has told the author that the Armory's piece work pay system would probably provide a strong incentive for innovation on the shop floor. For a discussion of how the Ordnance Department adjusted piece rates while still trying to provide financial incentives for production increases, see ARCO 1900, p. 99.

employees who have offered suggestions that resulted in material improvements and economies." The Chief of Ordnance admitted that the previous situation "had placed the Government in the unsatisfactory position of appropriating such suggestions and benefiting from them without suitable recognition of the authors."[928]

As we have described earlier, Colonial Mordecai in the 1890s would have no part of direct cash rewards for suggestions, but he clearly favored some men over others and had the power to help people in his employ. Demonstrating technical abilities had always been a way for a worker to attract the favorable attention of the managers who transferred men to better paid, more attractive jobs and selected the shop foremen. Under Mordecai, the military staff was more involved in promotion and job placement than had been the case in the past. Mordecai showed that he had few qualms about promoting junior men over workers with more seniority: "A, young, active, and good machinist was selected as a new foreman of the filing Shop..."[929]

Ideas for improvements in machining operations came from many sources both inside and outside the Armory. There was certainly collaboration among employees and between departments. It is not possible to apportion with any reasonable degree of accuracy the credit for incremental innovations among the various contributors at Springfield Armory in the period of this study, and probably not even in later periods for which oral history offers rich possibilities. What one can say with some certainty is that machine operators, toolmakers, foremen, draftsmen, engineers, and senior managers (including military officers) were all involved in the complex dynamics of technological change, in the give and take of ideas that kept improving production at the Armory.

Persistence of Hand Processes

With contributions from men at all levels of the plant hierarchy, the Armory was changing its manufacturing processes in very significant ways. The most important change was the elimination, through better machining practices, of extensive filing on "soft" parts, the steel components which had not yet been hardened by heat treatment. The 19th-century Armory had not achieved inter-changeability with machine production alone; many workers were still busy filing machined parts to

[928] ARCO 1912, pp. 901-902; Piaa, 1914, p. 10. A suggestion and reward program was more effective in World War II.

[929] ARCO 1894, p. 53.

gage by hand. In 1894, Colonel Mordecai criticized "the method formerly followed," in which "much of the work was not milled to gauge nor were the cuts smooth; as a result, the pieces had to be filed to the required size and finish, and much drawfiling was necessary." The following year, he proudly stated that "the `soft fitting' of certain parts was discontinued same months since and now the fitting required is the correction of those parts which may become warped or changed in the operation of hardening."[930] Examination of tool marks on Krag components suggests that his claim was overstated, but the physical evidence does demonstrate that machining operations alone brought many parts to the correct form and that hand filing (except for removal of burrs twin machining operations) was dramatically reduced during the Krag period.[931]

Many of the small parts of firearms had to be hardened before assembly and, because of their complicated forms, could not be ground to precise tolerances after hardening. Minor imperfections that were not detected before hardening or deformations caused by the hardening process could create problems. Some parts simply had to fit perfectly with others in the unforgiving mechanism that was a bolt-action rifle. Final fitting with a whetstone, which could shape or smooth steel too hard to file, was necessary for certain components of standard service rifles until the mass production of the semi-automatic M1 rifle in the early 1940s. In 1916, Colvin commented on the persistence of hand processes in making the 1903 Springfield, which replaced the Krag:
“In all work of this kind where close fits are demanded and where only very small variations can be tolerated, we see the great difficulty in getting away from the final hand-finishing touches. These are noticeable where all the close-fitting operations come together..."[932]

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[930] ARCO 1894, p. 53, 1895, p. 67. When machine tools could not produce a required shape or finish, Col. Mordecai favored rotary filing, a powered operation, over hand filing. However, some burr removal, touching up, and blending of machine cuts on soft parts was still done with hand files. Assemblers still used whetstones for fitting some hardened parts.

[931] We are grateful to Stuart Vogt for help with the examination of rifles in the collections of the Springfield Armory National Historic Site. Filing for burr removal was common at Springfield up to the early years of World War II, when better tumbling technology finally eliminated almost all of it. See Green, Vol. II, pp. 98-99, 238. This type of filing persists today in many factories.

[932] Colvin and Viall, pp. 103; Philip B. Sharpe, The Rifle in America, p.546. The receiver of the model 1903 was changed during preliminary design specifically to reduce warpage from heat treatment. This change is covered in Clark S. Campbell, The ‘03 Springfields, p. 4. Grinding is a machine process that will shape hardened parts. For a discussion of the use of grinding instead of hand fitting in the sewing machine industry to solve problems created by distortion in heat treating, see Hounshell, pp. 81-82. Hounshell, pp. 234, also discusses Colvin's observation that Ford Motor Company, which used many grinding processes, did no hand fitting in its assembly departments in 1913. Proof that the Armory got full interchangeability with the M1 rifle is in "Springfield Armory Monthly Report of Progress on Research and Development Projects," report of 20 July, 1943. Ten M1 rifles taken at random off the Springfield production line

Improvements in Production

While making progress in reducing the amount of hand work on the soft parts of the Krag, the Armory was also trying to regain lost ground in the struggle for interchangeability. Switching to a new rifle after 1892 had meant same setbacks as different manufacturing operations and gages were tested. By 1895, Colonel Mordecai could report that, with the use of "more perfect gages," the Krag was "practically interchangeable." Improvements continued each year. American Machinist said that in the "perfected model of '98 ... all the parts are interchangeable."[933] The term interchangeable was sometimes loosely applied (as we have seen, hand-fitting in assembly had not been completely eliminated), but the quality of the rifle and the precision achieved with machine tools had definitely increased in a short period of time.

The most important advances in the Armory's production technology during the period of the Krag were in the design of jigs and fixtures. Despite the complicated nature of many Krag parts and the increase in the number of operations required to make this bolt-action rifle, the productivity of individual machine operators was still impressive. This was primarily due to greater use of multiple jigs and fixtures that positioned several identical parts for a combined machining operation: "Mention should be made of the fact that, wherever it is possible, the work in the milling shops is done with double fixtures, two identical pieces being clamped in the machine at a time. In some of the later machines, indeed, Lieut. Dickson is using quadruple fixtures, all the parts of the new rifle sight which he has designed being machined on this system, the economy of which is obvious. Previous to 1881, all similar work in the shops was done with single fixtures."[934]

This use of holding or guiding devices for multiple parts became even more common during the

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were disassembled, had their parts mixed, and were then reassembled with no hand fitting or selection of parts. The design of the M1 rifle had a great deal to do with this achievement; many of the critical parts could be slightly outside the original gage tolerances and still function in the weapon. See Green, Vol. II, pp. 218, 473-474, 615-616. Grinding was technically feasible on the critical surfaces of only a limited number of M1 parts and was seldom desirable from a production viewpoint. Grinding operations on the production line had little to do with the elimination of hand-fitting at Springfield.

[933] ARCO 1895, p. 67; American Machinist (July 28, 1898), p. 557.

[934] "Manufacture of Krag - II" p. 330; ARCO 1894, p. 53. Many individual operations on the Krag were much more efficient in 1899 than they had been in 1894. When a new rifle went into production, efficiency fell and then began to rise again.

production of the Model 1903 Springfield Rifle. Double fixtures were involved in most milling operations. On one Pratt & Whitney Lincoln miller, a vise holding five tiny sleeve locks allowed an operator to rough cut all of them in a single pass. He completed this operation on forty-five parts every hour.[935]

Despite the many individual mechanical improvements, the Armory did not make much progress in the period between the end of the Civil War and the beginning of World War II, in terms of rifle output per worker per year. The increasing complexity of service rifles and the Armory's adherence to rigorous standards of precision and interchangeability kept this particular measure of efficiency down despite gains in productivity over the years of manufacturing each particular rifle.

The 1903 Springfield

The Armory developed and installed a production system for the Model 1903 in little more than two years. Extensive purchases of machinery in 1902 and of fixtures made from Armory drawings in 1903 upgraded and expanded the Armory's production capability without radically changing the basic manufacturing methods that had been used for the Krag. The two rifles were, after all, similar in many ways, and a great deal of the existing production technology could be retained. There was a continuing increase in the use of automatic machines, multi-spindle machines, and profiling machines; but much of the equipment ordered was "similar to" or "the same as" machines already in place. By far the largest purchase in 1902 was an order for 124 Lincoln milling machines. The emphasis on milling and special-purpose milling fixtures did not change.[936]

We know more about the operations on the 1903 Springfield than about the historical production of any complex mechanism. For some reason, historians have so far paid little attention to an amazing source of technical information, the incredibly-detailed and well-illustrated studies by Fred Colvin and Ethan Viall, associate editors of <u>American Machinist</u>. Their series of published articles in 1916

[935] Colvin and Viall, pp. 119-120.

[936] Proposal of January 10, 1902, and contract with Pratt & Whitney Co., December 21, 1903, RG 156/1382. Introducing new types of machinery could cause disruption of a manufacturing system; unless the potential gain in efficiency was clearly worth the disruption, a manager might decide to replace an old machine with one just like it or add extra machines of a type already in use. For a technical discussion of the similarities between the Krag and the Model 1903 designs, see Stuart Otteson, <u>The Bolt Action</u>, pp.29-42.

and 1917, prepared at the request of the Ordnance Department, were ostensibly to assist private contractors if they should have to make the 1903 Springfield during World War I (a practical impossibility given the lack of precise production drawings and the need for thousands of special jigs, fixtures, and gages). A special issue of American Machinist and a separate publication, United States Rifles and Machine Guns: A Detailed Account of the Methods Used in Manufacturing the Springfield, 1903 Model Service Rifle..., followed the serialized articles.[937]

Continuity in Stock-making Operations

Viall's description of the stocking process at Springfield in 1917 noted 37 operations in making the stock itself and 19 in making the hand guard, giving the number of times each operation was performed per hour or in an 8-hour day. Handwork remained an important component. We have calculated that the 13 hand operations for each gunstock-and-hand-guard took a total of slightly more than 36 minutes, while the 43 machine operations totaled about 29 minutes.[938] This was a decrease in the proportion of time taken by hand work since 1880, when Fitch estimated it at 5/8 of the total, as mentioned previously, but it still constituted somewhat more than half the time. We may also note that the total machine and hand time per gunstock (including hand guard) had dropped since 1854 from nearly one hour and a half, as mentioned above, but only to one hour and five minutes.

Viall noted that after the relevant cuts by machine, "Fitting the receiver is entirely a hand operation...by means of chisels gages and scrapers...The [trigger] guard is also fitted in the same way."[939] These two hand operations required, respectively, somewhat less and somewhat more than two minutes each.[940] The lengthiest hand operation remained, as in the 19th century, shaping and sanding to finish, in which "the operator," holding the work in a padded vise, "shaves butt to edges

[937] American Machinist, 1916 and 1917; Colvin, 60 Years, pp. 183-187. Colvin was primarily responsible for the analysis of metal-working processes on the Springfield, while Viall wrote the sections on the making of its wooden parts. Arthur Ormay produced the detailed drawings: there are 2337 figures, only a few of which are photographs. The entire study, with complementary materials as addenda, has been reprinted as Manufacture of the Model 1903 Springfield, Wolfe Publishing Co., Prescott, Arizona, 1984.

[938] Ethan Viall, "Making the Stock" and "Operations on the Hand Guard," in Fred H. Colvin and Ethan Viall, United States Rifles and Machine Guns, pp. 244-82.

[939] Ibid, p. 268. Although a gage was also involved, for "gages" here one should read "gouges."

[940] Production of 280 and 220 in eight hours equals 1.7 and 2.18 minutes, respectively.

of butt plate and top to form templet, then scrapes and sandpapers all over to finish," using "spoke-shaves, scrapers, and sandpaper." He was able to do 22 such operations in an eight-hour day, averaging almost 22 minutes each.[941]

The gunstocking machines depicted by Viall include many old and some new types. The old lock-bedding machine, for instance, seems to have been resurrected as a "turret-head bedding" machine, both to rough cut for the receiver and to cut for the cutoff thumb-piece.[942] The similar old machine for guard-bedding was still performing that function,[943] as were the machines for barrel-bedding,[944] turning for and between bands,[945] cutting top of butt for buttplate tang and boring it for butt-plate screws,[946] bedding for lower band spring,[947] and of course, for stock-turning, the "Blanchard-type lathes."[948]

The more general-purpose sawing, spotting, and boring machines were probably newer, as was certainly the illustrated machine for cutting grasping grooves.[949] The hand guard machines also include old-style, but presumably modified, machines for turning between and for bands and for barrel-grooving as well as for turning the guards themselves, typically from pieces of walnut salvaged from spoiled or obsolete left-over stocks.[950]

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[941] Ibid, operation 27, fig. 2064, p.267.

[942] Ibid., operation 8, fig. 1985, pp. 265, 258.

[943] Ibid., operation 17, fig. 2040, p. 264.

[944] Ibid., operation 7, fig.1939, pp. 245, 251-54.

[945] Ibid., operations 15,16, figs. 2023, 2028, pp. 261-62, 264.

[946] Ibid., operation 13, fig. 1942, pp.246, 259, 261.

[947] Ibid., operation 21, fig. 2045, pp. 264-65.

[948] Ibid., operations 5A, 5C, figs. 1936, 1937, pp. 245, 247, 249, 252-53.

[949] Ibid., operation 18, fig. 1943, p.246.

[950] The barrel-bedding machine, operated on the same principle as usual, is identified as a "Garvin special bedding machine." Ibid, operation 3, p. 273.

Continuing Emphasis on Millers with Special Fixtures

Colvin not only explained how the Armory made rifles but also evaluated the merits of the methods in use. He thought that "much of the machine equipment at the Springfield Armory, unfortunately, was very antiquated by contemporary standards," but he admired the adaptations of machines "already in the shops" and found this work "skillfully done in almost every instance." As we have seen earlier, he remarked on the predominance of millers, and he described the application of millers to some jobs "that we should be apt to consider lathe work." The preference for millers may not have been, as he assumed, largely a result of the accumulation of large numbers of these machines over time in gun shops.[951] Turning work in milling machines by rotating the workpiece against one or more cutters could be a more economical and rapid process than using a traversing cutting tool on the same piece in a lathe. Also, judging from Armory contracts for machinery, many of the millers in use at the government facility were not as old as they may have looked.

Since so many of the operations on the 1903 Springfield Rifle were done with specially-adapted milling machines, the Armory continued to favor the purchase of basic and inexpensive Lincoln millers which could be readily modified for particular operations with clever fixtures. Colvin said that "some of the fixtures made at the Springfield arsenal are of necessity elaborate in design and approach special tools in complexity." Although the Armory found good use for automatic screw machines and rifling machines on the production floor, many sophisticated and costly tools such as universal milling machines had more value in the hands of the toolmakers that made fixtures.[952] The Lincoln miller, with attached devices, remained the basic workhorse of rifle production at Springfield. It is still valuable today in the manufacture of high quality firearms.[953]

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[951] Colvin, 60 Years, p. 184; and Colvin and Viall, p. 101.

[952] See Colvin and Viall, p. 39; and RG 156/1382. A proposal for bids on an extensive list of new machinery on January 10, 1902 listed 124 No. 2 Lincoln Milling Machines and only three universal milling machines. The Lincoln millers have a hand-written price of $217.50 entered on the form. Although no price is similarly noted for the universal machines, the seventeen rifling machines were $810 each and the one vertical face milling machine was $650. As in many Armory proposals for new machinery, each universal milling machine was "to be a duplicate of one now in use at this Armory."

[953] The rifle production at what remains of the Winchester Repeating Arms Company in New Haven today (no longer a part of Olin) is still heavily dependent on Lincoln millers, set up with various fixtures.

Creative Adaptation and New Construction of Machinery

The Armory would sometimes order fixtures from outside contractors, but the designs for almost all special fixtures used in production or gaging came from within. Typical contract language for outside purchases said that the Armory "will furnish the specifications for these fixtures which consist of blueprints showing the construction and detail parts; patterns for the castings: also components showing the operation before and after the work have been performed." Such fixtures had to "pass a careful inspection at the Armory before acceptance for payment."[954]

Like other manufacturers with in-house talent in machine design and their own machine shops, the Armory sometimes built a machine "from scratch" or used elements of an old machine to make an entirely different one. In almost every case, the designers worked with available or newly-introduced technology, combining known forms and adding incremental innovations to meet the special needs of particular operations. Industries which break down their manufacturing processes into minute subdivisions and make heavy use of special-purpose equipment are most likely to generate a large number of incremental innovations. One interesting example in the 1916 Armory was an "old Ames profiler ...built over" as a single-sided broach for work on the trigger slot of the Model 1903.[955] This machine played a useful role in the production system, and its manufacture must have been less expensive than the purchase of comparable new equipment.

The Armory never had all the funding its officers wanted in this period, but appropriations were more generous during major retooling for new weapons and in wartime. Even when money was available for machinery purchases, the special needs of particular manufacturing operations sometimes made in-house production of machinery a reasonable alternative to outside purchases. Armory employees might need or prefer to build a working model of a special-purpose machine to test its viability, and for some operations on rifle parts one machine was sufficient. At any rate, it could be slow and costly to have a limited number of special-purpose machines custom-made by an outside contractor.[956]

[954] See articles of agreement with Pratt & Whitney Co., October 31 and December 21, 1903, RG 156/1382.

[955] Colvin and Viall, pp. 164-165. See also "Manufacture of Krag-II," p. 330, for a description of "an automatic machine designed in the shops, which drills simultaneously from each end" of the receiver.

[956] ARSA 1906, pp. 4-5. Building a working model or prototype is also for many machine designers a way to develop and work out ideas in three dimensions. We are indebted to Matthew Roth for his insights on the design process. It is

Machining operations on some parts of the Model 1903 were particularly challenging. Colvin said that work on the cocking piece involved "specially made tools and fixtures" that were "out of the ordinary." The cam on the end of this piece was "quite a particular piece of work" and great care was needed to "have the surface of this cam perfectly smooth." An ingenious fixture with a mechanically-guided rotation system made the operation possible on an upright drilling machine with an end mill for a cutting tool. Although the machinery worked perfectly while Colvin observed it, file marks on a cocking cam indicate that this was not always the case and that filing was sometimes necessary to attain the correct curve and surface finish. Armory production schedules, especially during the First World War, wore out tools, jigs, fixtures, and machines and put tremendous demands on machine operators who had to maintain the level of precision demanded by the military.[957] Keeping everything in perfect working order and avoiding human errors were admirable goals, but some problems were inevitable. A skillful touch with a file or a whetstone might save a valuable component from the scrap bin or make a part fit just right in a critical assembly.

Speeding up Production

The trend toward the acquisition of machinery that could perform operations rapidly was more obvious after the first decade of the twentieth century. High speed cutting steels, which were such a critical part of the movement known as Scientific Management, began to effect machining processes at a number of Ordnance Department facilities before the war. Many of the older machine tools could not handle the faster cutting speeds that new alloy cutting tools made possible. The introduction of higher speeds seems to have been a gradual process at Springfield, but in time it would help to create a strong demand for improved machine tools. The Armory purchased new furnaces for use with high speed steel cutters in 1908. A 1913 contract for Lincoln millers specified

difficult to tell from Armory sources in this period who is doing the designing and from whom the ideas come. As concepts of "Scientific Management" became popular (and controversial) in the early 20th century, trained engineers did play a greater role at the Armory and there was a tendency on the part of ordnance officials to question publicly the engineering capabilities of operators, machinists, and even foremen. The Chief of Ordnance in 1911 wrote about the importance of expert decisions and asserted that much of the new technology of metal-cutting was beyond the knowledge of the worker or the foreman; it was "without his ken." See ARCO 1911, pp. 13-14; and for a perceptive discussion of Scientific Management in the Ordnance Department, see Aitken.

[957] Colvin and Viall, pp. 123, 128; ARSA 1918, p. 1 and ARSA 1919, p. 1, both SANHS.

that "The bed is to be deep and is to be cast solid with a large oil pan, making an extremely rigid machine." The contract for this type of milling machine in 1902 had said nothing about the need for great rigidity, an attribute that becomes essential as cutting speeds increase.[958]

Automatic operation was another way to speed up production, and it sometimes provided an additional economic benefit by reducing the level of skill required to run a machine. The 1913 Lincoln Miller contract asked that the millers have "a power quick return attachment" designed to "knock off automatically" at the end of the stroke. Automatic profilers purchased from Pratt & Whitney in 1912 were to have separate spindles for roughing and finishing and "automatic feed and hurryup [sic] motion between parts to be milled upon." In 1906 the Armory "designed and manufactured" its own automatic screw machine for making windage screws, increasing production to 400 screws in eight hours. Only 168 had been made with the "hand screw machines previously used." A single operator in 1916 made firing pin sleeves for the M1903 rifle at a rate of thirty per hour in one operation on a Cleveland automatic screw-machine, using six different cutting tools. An Armory order with Brown & Sharpe Manufacturing Company in 1918 asked for automatic screw machines in three different sizes as well as automatic cutting off machines. By the end of the war, many operations were being done on automatic or partially automated machines.[959]

Possible Model 1903 lessons for Other Manufacturers

The lessons learned at Springfield, particularly in the area of jig and fixture design, had value in many other types of precision metal-working. Further research will be necessary to determine the influence of the Armory on other industries from 1892 to 1918, and after. It is clear that makers of such products as sporting firearms, sewing machines, watches, and bicycles had been borrowing ideas and hardware from so-called "armory practice" for years. The nature of "little kinks and devices," their amazing variety and their special applications, makes their ancestry hard to trace. Most evolved outside the patent system and are combinations of ideas from many sources. Sometimes their function was so job-specific that even brilliant designs received no attention outside a particular shop. Springfield Armory's jigs and fixtures, and, to a lesser extent, its cutting tools, were

[958] ARCO 1908, p. 59; Contract with Pratt & Whitney, 3 June, 1913, RG 156/1382; Aitken, pp. 79, 102-104.

[959] Contract with Pratt & Whitney Co, 4 June, 1918, and with Brown and Sharpe Manufacturing Company, 26 July, 1918, RG 156/1382; ARSA 1906, pp. 4-5, 13 and ARSA 1912, pp. 6-7, both SANHS; Colvin and Viall, p. 130.

among the best in America during this period. Many of them had much to offer perceptive designers of metal-working equipment in other industries.[960]

In some types of gaging and in the use of high speed steel cutters, the Armory apparently fell behind the highest state of the art in the early 20th century. In Chapter 3, we discussed the problem of tolerance or limit type gages, which did not appear in significant numbers at Springfield before 1908, and the need for outside assistance from the Greenfield Tap and Die Corporation on a major 1917-19 program to establish tolerances and to make necessary changes in the gages for Model 1903 Rifle components. Colvin scorned the lack of tolerances on rifle drawings in 1916 but praised the design of many Armory gages and the sophisticated fixtures for gaging operations. The purchase of new furnaces for use with high speed steel cutters in 1908, and the increasing use of heavier, more rigid machine tools that could handle high speed cutting, suggests that any deficiency in cutting tools was temporary.[961]

Colvin believed that "a close study of operations on the rifle, many of which are the result of years of evolution, will reveal a number of useful methods worthy of adoption as time savers." He found "many useful ideas regarding jigs, fixtures, and equipment." Small machining operations in various industries were often similar in purpose to those at Springfield, and "for that reason the fixtures used, the method of holding the work and the ways of gaging have a direct bearing on other work than rifle parts by a little modification and adaptation." It would, of course, be "necessary to adopt methods to your use, they seldom fit as you find them, ready made."[962] The publication of detailed process descriptions such as Colvin provided in American Machinist encouraged the transfer of methods and their adaptation in shops of different industries.

I. Limits to the Armory Production System in World War I

During World War I, the Armory was unable to meet the heavy demand for rifles. The maximum combined production of the model 1903 rifle by both Springfield and Rock Island Arsenal was

[960] For information on the development of a "rational jig, fixture, and gauging system" in a number of 19th-century industries, see Hounshell, pp. 6, 64, 72-81, 221, 117-122, 190, 193-194. For discussions of watch-making technology, see "The Building of a Watch," p. 132; and David Landes, Revolution in Time, pp. 314-316.

[961] See ARCO 1908, p. 59; Contract with Greenfield Tap and Die Corp., April 20, 1917, RG 156/1382; Earl McFarland, "Gaging the Springfield Rifle," pp. 367-369; Colvin and Viall, pp. 56, 58, 97; and Colvin, 60 Years, p. 186.

[962] Colvin and Viall, pp. 26-29, 97-98.

inadequate, and the Army had to turn to private makers who could manufacture the Model 1917 modified Enfield rifle in large numbers.

The government had not invested sufficient funds in the federal armories to allow them to meet wartime needs.[963] The Armory was not filled with the latest developments in standard machine tools when the nation entered World War I. The production equipment for the Model 1903 rifle still included many machines of older forms skillfully adapted for particular operations. Improvements in manufacturing since the adoption of a repeating rifle had come from better use of automatic and specialized machines, new tool steels, improved gages and inspection procedures, better routing of work in the shops, and most importantly, from the superb design of special jigs, fixtures, and tools for basic machines.

The overall system that had evolved by World War I was very impressive in a technological sense and much more effective than it had been in the early 1890s. Everyone seemed to agree that the product was exceptional: Philip Sharpe, historian of the American rifle, said in 1953 that the Model 1903 "is probably the most accurate military rifle in the world. It is certainly the finest and most precision-built piece of machinery any military organization has ever produced."[964] When industrial specialists looked at Springfield Armory between 1892 and World War I, they saw the cumulative effects of innumerable small changes in manufacturing technology. They saw operations that were, in Colvin's words, "the result of years of evolution." Scientific American found machinery not as elaborate as that used in watch-making, but shaving "a thousand and one 'wrinkles,' such as are dear to the heart of the machinist."[965]

The technical improvements at the Armory since 1892 were not enough, however, to meet the extraordinary need for small arms in the First World War. The Armory tried hard to make a dent in the demand for service rifles, but outside contractors ended up supplying most of the rifles that went

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[963] For a government perspective on this problem, see Benedict Crowell, America's Munitions. 1917-1918, pp. 177-184.

[964] Sharpe, pp. 117, 546. Sharpe did admit that the design of the model 1903 made it difficult to "produce precision in quantity." He understood the need for some hand fitting in a complex product that required incredible precision for perfect operation.

[965] Colvin and Viall, p. 28; "Manufacture of Krag-II," p. 330.

to the troops. The maximum combined production of the Model 1903 rifle by both Springfield Armory and Rock Island Arsenal was woefully inadequate for the needs of a mass army, and the military had to turn to private makers who were ready to manufacture the U.S. Model 1917, a modified British Enfield rifle, in large numbers. The government still had not invested sufficient funds in its federal armories to make possible a major expansion of their production capacity. Once America was in the World War, it was really too late. Springfield Armory reached a peak of production in the fall of 1918, when two shifts managed a total of 1500 rifles per day. The total production capacity of the three private factories making modified Enfields was close to 8000 rifles per day, and during the course of the war they turned out nearly seven times as many rifles as the two government plants. Private makers had invested heavily in new plants and machinery by 1917, and they concentrated on a simpler product that was less precise than the Model 1903 made at Springfield.[966]

As the war neared its end, the Armory took some major steps to improve its stock of machinery at the Hill Shops. In 1918, the Lincoln millers, which had been the workhorses of the production system since before the Civil War, were finally replaced by heavier millers capable of automatic operation. The new millers could take full advantage of the higher cutting speeds of the best tool steel. Other replacements followed. By 1919, the Commanding Officer could report that 271 machines "of improved types had been purchased and installed to replace less efficient and less modern machines."[967]

The Armistice created additional opportunity to upgrade and modernize equipment at the Armory. It "made possible procurement of government owned machines of latest types from commercial factories such as the Eddystone Rifle Plant, the Savage Arms Corporation, and the Remington Arms Company, Bridgeport and Ilion Plants." Approximately 1,600 machines from the private plants were transferred to Springfield, and hundreds of old machines at the Armory were condemned. The new machines, combined with a re-arrangement of departments and better routing of parts, were to allow a production capacity of 1,000 rifles, with spare parts and appendages, in an eight-hour shift.[968]

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[966] ARSA 1919, p. 1, SANHS; Crowell, pp. 177-184.

[967] ARSA 1918, p. 3 and ARSA 1919, p. 3, both SANHS.

[968] ARSA 1919, p. 3, SANHS.

This reorganization took several years and was linked to important changes in power generation and transmission, particularly at the Hill Shops. A central station at the Hill Shops navy used turbine driven generators to provide power for the electric motors that drove shafting for groups of machines on the shop floors. The Corliss steam engine and heavy main shafts were scrapped in 1919.[969]

J. Postwar Doldrums

The upgrading of equipment between 1918 and 1920 was not the beginning of a new age of expansion and modernization at the Armory. The demand for M1903 rifles faded after the close of the "war to end all wars," and the difficult job of reconditioning tens of thousands of returned rifles attracted little public attention and minimal financial support.[970] Although the Ordnance Department decided to expand its capability for pistol production at Springfield,[971] there was a sharp decline in the manufacture of all military small arms. The Armory could not keep its full force of skilled machine operators busy making .45 automatic pistols or replacement parts for the M1903 rifles of a tiny peacetime army.

The critical work at the Armory in the 1920s and early 1930s was in the development of a semi-automatic rifle. No one in the upper levels of the Ordnance Department wanted to take significant steps to modernize the production system of the Armory until a new semi-automatic rifle was adopted: design requirements had to precede production planning. In 1931, the commanding officer said that his failure to institute "very desirable changes" was because of "the expectation of a general re-organization when the type of semi-automatic rifle for the service shall be decided." In the meantime, problems with existing equipment were to be solved with a minimum of expense, usually by dipping into the remaining stores of machinery collected from the private arms makers after the

[969] ARSA 1919, p. 4, SANHS; Green, Vol. II, pp. 16.

[970] J. E. McInerney, "Overhauling the Service Rifle;" ARSA 1931, p. 6.

[971] Green, Vol. II, p.14. In 1917, the Armory had stopped the manufacture of automatic pistols and cut back on other products in order to concentrate on the M1903 rifle. At that time, the commanding officer said that experience "indicated very emphatically the error, from a manufacturing point of view, of imposing on a plant designed and laid out for the production of one article the manufacture of other articles even of a similar type." ARSA 1917, p. 2, SANHS.

war.[972]

This deferral of production planning was probably unique in Springfield Armory history. As discussed in Chapters 1 and 2, conservative Armory managers generally resisted new weapon designs requiring extensive changes in manufacturing methods. Even the Krag rifle, largely imposed on Springfield, succumbed to the persistent application of traditional Armory practice. After World War I, however, recognition of productivity limits in such practice, and of the radical new design likely for an acceptable semi-automatic rifle, gave Ordnance Department planners some pause. However, we cannot now distinguish how much of their prudence came from such recognition, and how much was simply an artifact of limited funds c1920-35. It is possible that the lack of money was an ironic, major factor in the later successes of the M1 era, if it prevented commitments to inappropriate methods and equipment. Abortive attempts to use M1903 fixtures and cutting tools on M1 parts in the mid-1930s, outlined in the following pages, suggest that senior Armory personnel were capable of such errors.

For our 1980s perspective, one important technological change took place in 1931, when Armory mechanics eliminated what may have been the last example of a hand-filing metalworking operation on a service rifle. The staff found that a machine operator could use a formed cutter to finish the striker point, making it perfectly hemispherical. This had been a manual operation after the M1903 striker was formed by an automatic screw machine (and further machined with a profiler). The filed point had then been finished in a lathe by an operator who polished it with emery cloth. The machine-made hemispherical point improved the indentation of the primer cup in a .30” caliber cartridge.[973]

As described in Chapter 5, there were also belated but significant improvements in metallurgical methods in this period. The biggest change in material for the standard rifle was the substitution of 3.5 % nickel steel for the old carbon steel used in receivers and bolts, although chrome-vanadium steels was tried for special parts in match rifles. This change in 1928 finally solved the problem of

[972] ARSA 1931, p. 4, SANHS; Green, Vol. II, pp. 51, 56. See ARSA 1930, p.13, SANHS, for cases of replacing machinery with items from the stored reserves.

[973] ARSA 1931, pp. 4-7, 10, SANHS; Colvin and Viall, pp. 131-132. Microscopic examination of indents in primer cups led to this change in manufacture.

brittleness that had been partially alleviated by a double heat treating process in 1917. The nickel steel alloy was clearly superior, but its toughness made it hard to machine. One important aspect of reconditioning was replacement of all receivers made before double heat-treating replaced case-hardening in 1918.[974]

Use of more modern steels soon created machining problems, and revealed new limitations of Armory facilities. By 1934, some antiquated machinery at the Armory had become an embarrassment for the officers in charge. Although no new service rifles were made in 1933, the Armory was trying to move ahead on the tooling required to make eighty examples of John Garand's experimental .30” caliber semi-automatic rifle, which was emerging as the clear choice for the next service rifle. In addition, there was a sudden and unexpected surge of orders for replacement parts for the M1903. To meet the latter demand, the Armory went to multi-shift production for a few months, and its Commanding Officer got a rude shock when the old machines began to fail:

> This strain on the machinery brought forcibly to light the extreme age and worn out character of the existing facilities and cast grave doubt on the ability of the Springfield Armory to duplicate its record of production during the World War without a large replacement program.[975]

As we have noted previously in this chapter, the production record to which he referred had not even come close to meeting the demand for rifles in the last war. He pointed out that few machines had been replaced since 1918, and that many dated from the turn of the century or earlier. In 1934, he went on to complain about the problems of machining modern steels with old machine tools:

> ...many changes in the metal used for rifles have taken place in the last decade, and nearly all have been at the expense of machinability. The resulting increased strain on equipment has and will continue to take its effect.[976]

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[974] ARSA 1927, pp. 7-9, ARSA 1928, pp. 7, 9, ARSA 1931, p. 6, ARSA 1932, p.4, ARSA 1933, p. 7, and ARSA 1934, p. 5, all SANHS; Sharpe, pp. 115-117; Campbell, pp. 18-19.

[975] ARSA 1934, p. 5, SANHS.

[976] ARSA 1934, p. 5, SANHS.

K. Retooling for the M1

Sensing a changing attitude toward military preparedness at higher levels of government, the Armory's staff saw a chance to upgrade their equipment. The frustrating conditions of the summer of 1933, when the Armory had operated with only a four-day week, were soon forgotten. In 1934, a program of modernization and physical expansion began that would continue up to the next world war. The War Department put in place a six-year program, to run from 1935 to 1940. Initially, this program for rearming the Army called for spending $150,000 per year to tool-up for the manufacture of the M1 rifle. Congressional support grew stronger as the decade progressed and as the threat of American involvement in European or Pacific conflicts increased. In 1936, the Armory spent $397,000 for machinery, tooling, and gages. In 1937, the expenditure was $455,000, and in 1939, it reached $1,122,000.[977]

The deterioration of machinery over time, without proper funding for replacement or overhaul, had already hurt the morale of Armory workers. The annual report of 1935 commented on this problem and expressed optimism about the retooling effort then underway:

> Inability to maintain the high standards of former years, for reasons largely beyond the control of either the Armory organization or the Ordnance Department, had begun to create an attitude of "Will it do?" rather than "Is it the best we can do?" Machinery capable of doing fine work is stirring up pride, and there has been and should continue to be a definite improvement in quality of product.[978]

When the Armory installed the first of their new general-purpose machine tools, they set them up with the old, M1903 fixtures and cutting tools, adapted for making M1 parts. This cost- and time-saving effort turned out to be a failure, because the old tooling could not take the strains of production on the high speed machines. In one case, "a fixture used on an old 18" miller was smashed by a new 12" miller when running at its slowest feed." The tough metals for many M1 parts were probably also a factor in the problems with old tooling, as they had proven to be in the recent production of modified M1903 parts at the Armory. By 1937, the usual orders were for machines with appropriate jigs and fixtures, and with written guarantees of production rates and

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[977] William H. Davis, "U. S. Rifle Caliber .30 M1," pp. 52-55.

[978] ARSA 1935, p. 13, SANHS.

accuracy.[979]

The goal promoted in 1938 was a new production system to equal any in private industry. The Commanding Officer said he wanted "to obtain ultimately a completely tooled plant second to none in methods." Only a few of the old machine tools had the accuracy or the speed of operation necessary for modern standards of manufacturing.[980] The Armory would not just make improvements in the most backward areas of its production, as it had in previous partial modernization efforts stretching back to the mid-nineteenth century. It would not just continue the normal practice of upgrading production with better jigs, fixtures, and cutters on out-of-date machine tools. This time the mandate was much more sweeping: to develop the best available system, as fast as possible. By 1938, the small size of the standing army in the face of a threatening world situation, and the brilliant but complex nature of John Garand's new rifle, gave the Ordnance Department a challenge as clear as it was urgent: it had to find a way to manufacture enough of these intricate weapons to supply the vast army that might be needed in the immediate future.[981]

Proponents of the Johnson semi-automatic rifle said the Garand rifle, whatever its firepower, could not be mass-produced. They argued that the Army was adopting a rifle which was essentially a custom-made product.[982] They might have been proven right were it not for the fact that Garand was as gifted a production engineer as he was a rifle designer. The planning division of the Armory carefully selected machinery, seeking the best ideas and the most modern equipment from many sources in private industry. Armory engineers worked closely with machine tool suppliers to find the optimal ways to manufacture each of the parts of the new rifle. Despite the efforts of hundreds of production specialists inside and outside the Armory, Garand had to solve many manufacturing problems on his own. He had designed the rifle with mass production in mind, and he was the guiding force as the production system began to take shape. Both the rifle and the planned production system went through many changes and refinements in this period. Garand's initials on

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[979] ARSA 1935, p. 10, and ARSA 1938, p. 41, SANHS; Green, Vol. II, pp. 67a, 69.

[980] ARSA 1937, pp. 38, ARSA 1938, pp. 41, SANHS.

[981] Davis, pp. 54-55.

[982] Davis, p. 53; F. Blake Stevens, U.S. Rifle M14 from John Garand to the M21, p. 8.

many drawings for this retooling effort show that he was as concerned with production as he was with rifle development.[983]

The Model Shop, which was also Garand's workshop, was deeply involved in work on the fixtures and tools for the new rifle in 1938. The annual report of the Armory provides a long list of specific work by the shop "pertaining to the U.S. Rifle Cal. .30” M1." Garand and his helpers in the Model Shop were solving problems whenever serious difficulties arose, designing fixtures and gages to correct specific operations and trying innovative manufacturing methods, such as resistance welding for the operating rod. The commanding officer stressed the importance of the shop's cooperation with Production Engineering on this retooling effort.[984] However, this cooperative environment did not last for long. The production engineers eventually took over most of the retooling effort and largely eliminated Garand's direct involvement. Maj. Gen. Julian Hatcher feels that Garand was treated badly by the Armory as the rifle went into full production.[985]

When production engineers could not find a good way to make the M1 hammer in 1939, the Model Shop took the unusual step of designing and building two special machine tools, one a profiler and one a miller. The annual report said that these highly efficient machines were "a considerable variance from accepted practice." Perhaps the successes of the Model Shop in this retooling period were an embarrassment to the Production Engineering Branch. Jealousy may explain what General Hatcher sees as an effort to freeze John Garand, "a topflight machine tool designer," out of much of the retooling project. Hatcher says that "A fundamental mistake was made that Garand was not consulted in connection with the actual details of the tooling for many of the parts."[986]

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[983] Col. James Hatcher, quoted in Julian Hatcher, The Book of the Garand, pp. 117-120. The Springfield Armory National Historic Site has organized the tooling drawings and has produced a computer printout of them. We are indebted to Richard Harkins for noting Garand's initials on many of them.

[984] ARSA 1938, pp. 33-34, SANHS. Green, Vol. II, pp. 80-81 has a copy of a memo from the commanding officer to the works manager on Sept. 28, 1937 asking for a study of all components by the "Engineering Section of the Planning Division in cooperation with shop officers and the Research and Development Department." The study was to find ways to simplify manufacture of each part, "rendering it capable of quantity production." Any changes in the components, their materials, or their tolerances had to have the involvement and approval of the Research and Development Department and therefore, one may assume, of John Garand. ARSA, 1940, p. 35, says, "the Model Shop has been directly engaged almost exclusively with the development, production, and determination of methods to overcome certain difficulties encountered with the M1 Rifle."

[985] Hatcher, p. 120.

[986] ARSA 1939, p. 18; Hatcher, pp. 120. Hatcher says an Armory officer actually suggested laying Garand off to save

Makers of machine tools and special tooling were eager to take part in the process of re-equipping the Armory. The Depression had hit them particularly hard, and they needed orders to survive. They studied the sample M1 parts provided by the Armory, solved particular production problems presented by this complex rifle, made suggestions, designed some new machinery and a great deal of special tooling, submitted bids, and offered the production guarantees that the Armory demanded.[987] They also made changes in their delivered equipment as necessary to meet the stiff specifications and to honor their guarantees. There was also the potential for even more orders if, as many experts anticipated, one or more private firms were to receive contracts to make some of the new rifles. This amazing co-operative effort between private and government technical specialists reached its peak in 1938. In that year, the first production run of the new rifles was completed by Springfield Armory: 1,500 M1s, made with a mixture of new and old machinery, went to the 29th Infantry Division for field testing.[988]

The Commanding Officer praised the help that the Armory received from "the most successful machine tool producers, tooling producers, and engineers available." He said that his staff got the "fullest and most hearty cooperation from industry." The goals of this retooling effort, as stated in 1938, were: "accurate workmanship, eliminating the requirement for complete gaging, conserving of space, and a high rate of production..."[989]

Even Armory stocking machinery, whose early sophistication allowed for relatively easy adaptations to new rifles from c1855 to World War I, now experienced a complete break with the past. Armory management realized that they needed a wholesale replacement of the old machines and methods, "some of them in use since Spanish-American War days."[990] Others were thought to

his salary of $3,500 dollars per year. It is clear that not all Armory officers agreed with this ridiculous proposal. Davis, p.77, seems to have made a mistake here when he credits the Experimental Department (Model Shop) with making only one automatic machine to solve these problems.

987 ARSA 1938, pp. 40-41, SANHS; Davis, pp. 53, 56, 60-61.

988 Davis, 53-57.

989 ARSA 1938, pp. 40-41, SANHS.

990 Onsrud Machine Works, Inc., Bulletin 1103, "Onsrud and the Garand," SANHS.

be even "as much as 75 years old", i.e. dating to the Civil War.[991] Garand's specifications required tolerances as small as .0015 inch for wood as well as metal components,[992] and the old machines simply could not cope.

High-speed tool steel had entered the modern parameters for planning machine production of both wooden and metal manufactures. By 1938 appropriations came through for re-equipping the stocking shop and a set of new machines was supplied by Onsrud Co. in Chicago, which had been studying the task in consultation with Springfield civilian and military engineers. After starting with an output of 300 sets of stocks and hand guards per day, the machines were augmented in number after demand rose to 1000 a day in 1939 and even higher when World War II began. During the war, when the stocking shop was operating around the clock, 125 Onsrud machines produced 6,000 sets per 24-hour day.[993]

Except for the Onsrud W-450 copy lathe, which should be regarded as a third-generation Blanchard lathe, these new machines bore virtually no resemblance to their special-purpose predecessors. They were for the most part general-purpose woodworking machines--routers, shapers, and boring machines--equipped with special fixtures to adapt them to the specific tasks of stock and hand-guard preparation. The automatic shapers each had a rotating circular table with multiple fixtures so that they performed different cuts on several stocks at once in a continuous-feeding process. The anonymous writer of the Onsrud bulletin describing this machinery tallied 65 operations performed in 19 steps or "set-ups" of ten different kinds of machine, only one of which he termed "special." The other machines, he said, the readers ("those in woodworking") would probably recognize as used in the trade generally.

With their high-speed cutters (21,000 and 30,000 rpm) and multiple loading capabilities,[994] the Onsrud machines were much more rapid in operation than the 19th-century machines they replaced.

[991] Green, Vol. II, p. 71a, p. 236.

[992] Onsrud bulletin.

[993] Ibid.

[994] Green, Vol. II, p. 197.

The stock-turning operation still took the longest, but at 2.77 minutes per stock, it was significantly faster than the 4-8 minutes of the lathes of 1853, shown in Table 7.2. Most of the other 18 operations took 12 seconds per stock.[995] The machine times for all 19 operations totaled just over seven minutes and twelve seconds per stock, instead of the total of 22 minutes, 44 seconds per stock for the stocking machine times in 1853, or the 23 minutes, 10 seconds total reported by Viall for the machines in 1917.[996] Clearly, a breakthrough had been accomplished in reducing the machine time required to produce gunstocks.

But what about the remaining hand work, which constituted so important a part of the total production time both in 1853 and in 1917? Although Thomas Blanchard himself had in 1854 developed and patented a flexible belt sanding machine that was suitable for smoothing irregular products of his lathe, such as ax handles or wheel spokes,[997] no such machine has shown up in the records of the Springfield Armory stocking shop for all the years before the Onsrud machines were installed, nor did the Onsrud stocking production line include such a machine. The last machine in that sequence, a "special double-head radial arm shaper," was said only to save "a good portion of the finish sanding time formerly required."[998] Yet at some point "sanding belts" had indeed been added to the system, to replace or at least diminish the hand-sanding described by Viall in 1917, for they were mentioned in passing in 1943. Apparently the turning lathes had been running more slowly than their full capacity, for they were speeded up from 3 minutes 50 seconds to their advertised speed of 2 minutes 45 seconds per stock. The work pieces, which emerged rougher, nevertheless "required no added time on the sanding belts to finish."[999]

Success in manufacturing the new rifle did not come easily, however. The early production runs showed the potential of the modern machinery and tooling, but also demonstrated once again that

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[995] The Onsrud bulletin shows an output of five per minute for twelve of the 19 steps.

[996] This calculation excludes hand-guard production in both the Onsrud and Viall cases.

[997] United States Patent #10,497, "Machine for Polishing Plow Handles and Other Articles," Feb. 7, 1854. Blanchard's machine held and fed the workpiece automatically past the moving abrasive belt. He did not claim the endless "polishing" belt itself as part of his invention, which implies it was already known.

[998] Onsrud bulletin, step #19.

[999] Green, Vol. II, p. 364. Sanding operations are pictured p. 235b.

any radical change in the service rifle would cause temporary setbacks in the accuracy of production at Springfield Armory. In this case the usual difficulties in switching from one rifle model to another were magnified by a simultaneous revolution in basic manufacturing technology and the presence of many new workers. The Commanding Officer admitted that "A high percentage of work not to drawing naturally resulted from starting a new production output with newly designed, untried tooling combined with an almost complete complement of machine operators strange to the type of work carried on here."[1000]

The buildings were also being improved and plans laid for physical expansion. When a new concrete floor replaced the basement floor of building #101 in 1937, this rehabilitation was related to the performance of the new machinery. Automatic machines were moved onto the new floor, which provided "a better foundation for the fast moving machines and is reflected in their product." In 1938 the Commanding Officer complained about the condition of many of the old shop floors and discussed the reflooring program that was then underway.[1001]

By 1940, the Armory had made considerable progress in a "departmental program to eliminate all the overhead countershafting" in its production shops. Much of the new machinery was arriving "with motor drive," and others were being motorized. Two lines of countershafting were gone and the remaining line was scheduled for removal in the next fiscal year. Among the equipment in the list of purchased machinery for 1940 were "35 individual motor drive attachments." New electrical and hydraulic drives and controls on purchased machinery were, however, creating maintenance problems for the Armory workers. The proud Armory had to turn again for outside help: "In this connection, employees have been given the opportunity to visit other plants to get first hand information regarding the maintenance of modern equipment."[1002]

New machinery for the M1 production lines was largely in place by the end of fiscal year 1940, with

[1000] ARSA 1938, p. 40, SANHS.

[1001] ARSA 1937, p. 48, ARSA 1938, p. 40, SANHS.

[1002] ARSA 1940, pp. 41, 43-44, SANHS. A big step in motorization came in 1935 with the overhaul of 34 rifling machines. The annual report remarked on the "improved working conditions arising from the absence of belts." ARSA 1935, p. 13, SANHS.

some machines still on order and several "not accepted due to the inability of the builders to meet their guarantees of accuracy and production." Older machinery filled the gaps temporarily, and the output of M1 rifles rose impressively month after month (the fiscal year production totaled 33,243). The long lists of new machines reveal the usual large proportion of millers, but automatic features were now common on these machines. Fifteen high speed profilers and a number of broachers had arrived in 1939, along with various types of grinders. The Armory accepted 249 machines in Fiscal Year 1939 and 468 in Fiscal Year 1940 (fiscal year goes from July of the previous year through following June). In the latter year, the total cost of machine tools was $1,183,000.[1003]

Constance Green, Armory historian during WWII, claimed the rush orders for new machines caused some problems with adjustment after arrival. The difficulty was "partly because the castings, not sufficiently seasoned, tended to warp after the machines were set up." Although it is difficult to evaluate this claim, since other factors might have been involved, the new equipment was very welcome at the time.[1004]

The Effects of M1 Re-tooling an Wartime Production

The traditional types of machining in which the Armory had long excelled (milling, profiling, turning, boring, and drilling) were being improved with faster machine tools, increasing use of automatic controls, and better jigs and fixtures. Other forms of machining, in particular broaching and grinding, were being applied with considerable success. Broaches, which could do some of the work once done by millers but with higher productivity, were to become more and more important in the production of the M1 during the war. Grinding, a very precise machine process which can shape hardened parts, played a larger role in the manufacture of the M1 than it had for the bolt action rifles. The Armory added centerless grinding of parts to its repertoire during this period.[1005] But grinding was technically feasible on the critical surfaces of only a limited number of M1 parts and, because of production considerations; its use was often rejected in favor of faster methods.

One can get an idea of the range of machining operations used on one small part by examining a set

[1003] ARSA 1939, pp. 32-40, ARSA 1940, pp. 44-49, SANHS.

[1004] Green, Vol. II, p. 458.

[1005] Green, Vol. II, p. 197.

of labeled photographs showing the making of the M1 rear sight aperture in c.1941. The operations included milling, broaching, surface grinding, drilling, countersinking, gear cutting with a shaper, rough-cutting with a hand screw machine, facing with an automatic screw machine, and tumbling for burr removal.[1006]

Grinding was more common in work supporting production than on the actual production lines. The precision of grinding, the smooth surfaces it created, and its ability to cut already-hardened steels were particularly valuable in gage-making and in preparing tools, jigs, and fixtures for use on the machine tools in production shops. Too often a soft piece carefully-machined on a miller would warp when it was hardened; with a grinder you could harden before finish grinding. Toolmakers worked with grinding machines to create many of the production cutting tools, although increasingly the Armory was relying on outside sources for its cutters. Tool sharpening was the largest job for grinders at the Armory.[1007]

Individual sharpening of steel cutting tools had persisted at Springfield until the mid-1930s; almost a half century after Frederick Winslow Taylor had begun protesting the time machinists wasted leaving their machines to sharpen tools. A machinist usually did this by hand on pedestal grinding wheels, taking justifiable pride in his ability to rework his own cutters. In 1935, the Armory started insisting on central grinding of tools, and made machine operators turn in their dull tools for sharpening by someone else. The goal was a ready supply of interchangeable tools ground efficiently by machine to the correct shape. This would place tool grinding on a "semi-production basis." Two years later, the commanding officer said that the policy was "now approaching a stage of acceptance by the organization," although he admitted that the quantity of sharp tools produced was not yet sufficient. With the purchase of more grinding machines soon after, centralized sharpening became standard practice.[1008]

Experiments with tungsten carbide tips on steel cutting tools led to many successful stock-making

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[1006] Green, Vol. II, Book II, appendices, plates 1-12.

[1007] We are indebted to Richard Harkins for his knowledge of Armory grinding practices and cutter procurement. He first made us aware of the predominant role grinders played in tool sharpening.

[1008] Green, pp. 72-73; Aitken, p. 22; ARSA 1935, p. 12, ARSA 1937, p. 50, SANHS.

and metalworking applications from about 1940 on, greatly decreasing stock-making machine times and facilitating barrel turning. With carbide, time was saved on sharpening, and higher rates of metal removal were possible, but replacing tips was still done laboriously by torch in 1944.[1009]

Better forging meant less cutting, less wear on machines and tools, and less waste of high demand steel. A new forge shop, opened at the Water Shops in the fall of 1941, had excellent drop hammers and dies. Receiver forging was particularly impressive. Springfield took pride in using a smaller number of hammer blows than Winchester did to forge an M1 receiver, which then required less machining than Winchester's product. In addition, there was a substantial savings in raw material with the Armory's methods. The Armory had begun purchasing already-forged, tapered blanks for its M1 barrels in 1940. This change, from the earlier use of bar stock, was another way the Armory saved on alloy steel and on forging and machining time.[1010]

Broaching probably contributed more to higher rates of M1 rifle production than any other machining process. Broaching machines and their cutters were expensive, but they could do many operations more rapidly than millers. In 1940, Ivan Swidlo, the civilian head of Production Engineering, began replacing milling operations with broaching. In one test period, three operators running eight broaching machines manufactured as many parts as twenty-three operators running sixty-one milling machines. As broaching operations proliferated, the Armory ran into trouble getting additional machines for operations on the M1 receivers. Receiver production was held back for several months in the summer of 1943 until the four heavy broaches arrived. Then production soared--from a normal rate of 75,000 rifles a month to 113,285 in the month of October.[1011]

Broaching solved the problem of finding machines to rifle .45 cal. pistol barrels when the Armory got that job in 1941. The staff developed a way to do the rifling with broaches. "Machine operators" modified "two obsolete screw-type broachers" to do the job faster and with more accuracy than was possible with traditional rifling machines. The broach rifling process was applied to .50” caliber

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[1009] Green, Vol. II, pp. 106-107, 595, 774.

[1010] Green, Vol. II, pp. 100, 103.

[1011] Ibid, pp. 96a-b, 237, 341, 347, 350-351; Davis, pp. 69, 77-79.

machine gun barrels in 1942 with great savings in man hours and floor space.[1012] As we will see later in this chapter, broach rifling equipment for .30” rifle barrels was apparently not in place until 1955.

Swidlo also developed hydraulic shavers, to replace the much slower mechanical types then in use; and he designed automatic two-spindle profilers, two of which could be run by one man. This improvement in profiling technology quadrupled the usual output of an operator. As World War II continued, multi-spindle and multi-station machines became high priority items at the Armory, but most of them were purchased from machine tool manufacturers. A multiple unit Kingsbury Machine drilled, reamed, milled, and cut slots on the rear sight base. Its operator had to handle the part only once.[1013]

L. Wartime Refinements, 1941-1945

Quantity of production had to go up to meet the constantly increasing demand for rifles in the first two years of the war. Machines such as broaches and multi-spindle or multi-station equipment of various types increased production but often with some sacrifice of quality. Millers could hold closer tolerances than most of this advanced machinery. In order to avoid excessive rejection of parts made on the high-output machinery, the Armory had to loosen some of its specifications and allow the use of many parts that did not fit the drawing tolerances.[1014] As shown in Chapter 3, the official tolerances were usually more demanding than was necessary for proper functioning of parts in the rifle.

The Armory's usual obsessive concern for quality did not disappear entirely, however. When Winchester, after an initial "educational order" in 1939, got contracts to begin manufacturing the M1 rifle, the quality of production at the private firm was the cause of much criticism from Springfield. The Armory made some necessary compromises during the war, but always considered its M1 rifles

[1012] Green, Vol. II, pp. 103, 234-235.

[1013] Green, Vol. II, pp. 96b-96c, 197, 774. For some of the many other examples of machining improvements, see pp. 230-231, 235.

[1014] Ibid, pp. 618-619, 805.

superior to those made by Winchester.[1015] The lightweight carbine designed by Winchester may have satisfied an important military need cheaply and rapidly, but its sloppy construction was an affront to Armory purists. Equally distressing to members of the old school at Springfield was the simplification and cheapening of the sacred M1903 rifle in wartime production by Remington. The Model 1903A3 of 1943 had a number of stamped or pressed steel parts. The condescending attitude toward less precise, but admittedly functional and inexpensive, weapons is perhaps best expressed in Armory employee and historian Constance Green's discussion of the submachine gun designed and manufactured by the Inland Division of General Motors, with brilliant substitution of sheet metal stampings for normally forged and machined parts:

> The M3 was almost like a Woolworth imitation of a fine article, but it achieved the purpose of its designers, namely effective functioning and sufficient durability, easily manufactured and obtained at enormously reduced costs.[1016]

The Armory's rifle designers and production specialists were slow to develop a real appreciation for metal stampings in military rifles despite their marginal involvement in the development of the carbine, the model M1903A3, and the M3 by private industry. Late in 1943, stampings were finally approved for the trigger guard and bullet guide of the M1. When put into effect at Springfield in 1944, these stamping operations cut costs and, even more importantly, allowed the use of inexperienced machine operators, including women.[1017]

The loss of skilled men because of the draft, voluntary enlistment, and more lucrative job offers had become a very serious problem. It directly affected the choice of machinery and tooling for a number of operations. Operators could run many semi-automatic or automatic machines with only minimal training, a great advantage during the war. Adaptation of existing machines alleviated some problems. Fixtures were designed with electrical sensors to assure proper seating of a part for an operation, others were modified to apply air pressure for clamping work quickly and accurately.

[1015] Davis, pp. 60, 64-66, 90-91. Davis also includes several reports on Winchester production in his appendices.

[1016] Green, Vol. II, pp. 242-244, 254-255.

[1017] Ibid, pp.486-487. Surprisingly, Green seems hesitant in her praise of the many contributions of women workers at the Armory. She does credit them with having better sensitivity with their fingers, and cites the Superintendent of the barrel shop, who "pronounced the women operators more adroit, quicker, and more painstaking than men." See ibid, pp. 350-351.

New operators could maintain high rates of production and minimize rejections with this kind error-reducing equipment.[1018]

Better fixtures improved productivity in many ways. Some raised the percentage of acceptable components. Others reduced the time it took an operator to set another piece (or pieces in the case of duplex or multiple fixtures) in position for a machining process. Reduction of machining time was important, but time saved in loading and unloading a fixture could be just as valuable. Green refers to "constant engineering study of the fixtures which held in place the work to be machined." Here there were contributions from every level, from the officers and production engineers to the machine operators.[1019]

A Suggestion Box program yielded about seven usable suggestions every month, providing ideas for faster or better methods or devices which netted their originators anywhere from $5 to $250 in cash awards from a grateful Government, and saved the Armory many times such sums in material or operators' time. Ideas were actually "pouring in." In one six-month period, ten times as many ideas were turned in as were adopted. The demands of wartime production made it impossible to put all the worthwhile suggestions into effect, however. Green also noted that "Many ideas emanated from lower ranking supervisors in charge of an operation who, more interested in speeding up the work than in a few dollars in their own pockets, might choose to have the innovation approved by the production engineer in charge rather than submit it to the inevitable delays of going through the Suggestion Box." Despite the considerable contributions of workmen, Green did acknowledge that "the main responsibility for devising improvements in manufacture was, as always, borne by the engineers and the Army officers and civilians in charge of the shops." The engineering staff and supervisors "unceasingly found minor improvements of fixtures or feeds," and "no process was ever viewed as perfect beyond the possibility of betterment."[1020]

Wartime also meant occasional difficulty acquiring new machine tools, either to replace those that wore out or to change production methods. The delay in getting broaches for the receiver operations

[1018] Ibid, pp. 487-488.

[1019] Ibid, pp. 485-488.

[1020] Ibid, pp. 485-487, 497, 627. From January to July, 1944, 495 suggestions were turned in, and 45 were adopted.

has already been mentioned. A 1943 redesign of a hammer spring plunger made possible its manufacture on cold-heading machines, but the Armory had none. The solution was to buy the parts from an outside supplier whose heading machines made plungers from coiled wire at a rate twenty times that of the milling machines formerly used. Other inexpensive small parts, made by cold heading machines and purchased in large quantities, provided similar savings of time and money.[1021]

The necessity for immediate replacement of several M1 parts that had proven inadequate in combat forced the Armory to contract for machining services. All M1 rifles in use or in production were affected. Because of the sudden demand for literally hundreds of thousands of these components in 1942, and the limited number of machines which could do the work at the Armory, some of the operations on the new rear sight elevating pinion and nut were performed elsewhere.[1022]

The manufacturing line at the Armory that was by far the most productive during WWII was a radical departure from past practices and, technically, did not make a component of the M1 rifle. It was the line set up to produce the ammunition clips that a soldier had to insert into his M1 to load it for firing. Formed from sheet metal, these inexpensive and disposable items were needed by the millions. Their successful manufacture using a number of advanced (or at least unusual) technological processes helped promote the diffusion of these methods into other areas of Armory work.

Stamping presses proved very effective in making clips, but the process left burrs and sharp edges. In 1937, tumbling the clips provided the easy solution, one that had long been used for cut nails. The Armory added a new factory building for clip manufacture in 1941. Two years later, the introduction of conveyors, gravity chutes, automatic feeds and gaging devices, and the addition of some faster machines to the line raised the production rate to 100,000 clips per day--and required fewer workers. The clips moved from one operation to another without any manual effort, and even electric gaging took place at a series of stations along a chain belt conveyor.[1023]

[1021] Ibid, pp. 224-226.

[1022] Ibid, pp. 224-225.

[1023] Green, pp. 97, 482-484.

The tumbling of selected M1 rifle components, and the use of stamping presses already mentioned in the previous paragraph, did not come directly to the Hill Shops from the clip manufacturing line, although the experience there was helpful. Tumbling was apparently introduced for a few of the smaller M1 parts in 1940, after man in the file and polish shop learned of similar tumbling operations used by Singer Sewing Machine Company. A great deal of trial and error was involved adapting tumbling to rifle work because of problems with deformation and damage of critical machined surfaces. Efforts to develop an acceptable tumbling process for receivers were unsuccessful until the fall of 1943. However, burrs on receivers still required some filing in 1944, when the Armory put marked photos at the work benches to show the receiver surfaces that really needed filing. There is also evidence of preliminary filing for burr removal on bolts and hammers before they were heat-treated and finally tumbled in barrels. Some filing persisted through World War II and the Korean War.[1024]

The Armory began the belated adoption of conveyors, long a fixture in private manufacture, during World War II. The first such use at Springfield was probably in horizontal feeding of rifle barrels through heat treating furnaces. Lindberg Furnaces, equipped with automatic conveyors that kept the barrels vertical, began arriving at the end of 1941. They were a great improvement, because the vertically-hung barrels no longer sagged and, therefore, did not require subsequent straightening. In less than two years, overhead conveyors were also saving space in the barrel shop and reducing the need for strong men to move materials around. The addition of roller conveyors to the milling shop in 1943 eliminated heavy tote boxes of receivers and fed components automatically through washing vats. Conveyors assisted in greasing and packing operations in 1944 and in the firing, cleaning, and inspection processes of the Assembly Department in 1945.[1025]

Conveyors were part of two changes in stocking shop procedure which reduced overall work time. One was the installation of an overhead system of conveyor racks in early 1942 to carry the stocks

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[1024] Ibid, pp. 97-100, 238, 767. SAHS, 1 January 1955 - 30 June 1955, Historical Report of the Hill Shops, discusses experiments with a new tumbling machine for M1 receivers, "to eliminate considerable hand burring operations."

[1025] Ibid, pp. 226-229, 341, 363, 482-484, 488, 772,-773; Davis, pp. 69, 82.

through the production line in two hours.[1026] The other was the adoption of oil dipping vats with much larger capacity than the one described by Viall, which was only 48"x 16" x 16". In the 1917 method, "the operator dips stock in boiled linseed oil, lets it drain and then places it in a rack to dry over night," at a production rate of 150 per hour.[1027] The 1942 method programmed the conveyor to submerge the stocks and guards into baths of chinawood (Tung) oil, bringing them out again at the end of the required five minutes "without workers' having to come near the vats of inflammable oil."[1028] One stock could run through the production sequence in 29 minutes instead of two hours, but the main value of the conveyor racks was to make possible between-machine handling of the large numbers of stocks now under production in outgrown shop space. By eliminating hand-trucks from the workshop floor, the conveyor allowed closer spacing of the machines.[1029]

Tool breakage and "down" time of the stocking machines was much reduced by an electro-magnetic metal detector installed in 1943, through which the walnut blanks were passed before machining began. Thus blanks with nails or barbed-wire fragments buried unseen in the wood were removed before they could damage the machines.[1030]

By June 1943, the Armory had become a plant for the specialized production of only a few products, most notably the M1 rifle and .50” caliber machine gun barrels. The diversified manufacture which had marked the first years of the war was gradually eliminated, with most of this work farmed out to private contractors or other arsenals. During 1943, even the 555 men in the Job Shop, most of them skilled machinists and toolmakers, found themselves in other positions, usually on the M1 production lines. The Armory reported that the total number of M1 rifles it had produced in fiscal year 1944 was 1,160,420, at a unit cost of only $26.27 per rifle. Production at Springfield had hit a peak of 122,001 rifles in January of that year and had then declined gradually as the Ordnance

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[1026] Ibid, p. 235a.

[1027] Viall, operation 28, fig. 2066, pp. 266, 267.

[1028] Green, Vol. II, p. 236.

[1029] Ibid.

[1030] Ibid, p. 237.

Department cut back its estimates of the rifles that would be needed to win the war.[1031]

The incredible pace of production had worn out many machines and fixtures, requiring extensive replacement of equipment that was often less than five years old. Machinery, tooling, and operators may have been pushed too hard, but the Armory had in this war met the challenge it had failed to meet in World War I. Its rate of production for the M1 rifle far surpassed that of Winchester, and its unit costs were much lower. In addition it usually turned out one hundred spare parts for every rifle it made. With the demand for parts rising because of heavy combat in 1943, the Armory made 9,125,253 spare parts and spare assemblies in the last six months of the year.[1032]

The Armory shared three basic problems with most private industries doing war production. First, there was a shortage of tools and fixtures as the Armory struggled to complete the retooling for mass production of the M1. Second, there were a number of shortages or mistakes in the delivery of raw materials in the first years of the war, including one serious but soon-corrected cancellation of the supply of receiver steel. Finally, the shortage of skilled workers became a major concern by 1944.[1033] Meeting the production challenges of World War II more than answered any questions previously raised about the value of a government small arms factory. Procurement politics and Armory affinity for established procedures made for a very different story as the war ended, however.

M. Retaining "The Art of Small Arms Manufacture" c1945-1957

Closure of the Job Shop during the war confounded Armory officials by 1944. They concentrated primarily on one product, but they would soon have more of that product, the M1 Rifle, than the Army needed. They realized that they had given up an ability to make diversified products and to test out various methods of manufacture, eliminating "the Army's bank of small arms human and physical investment." Quickly, they re-established this shop, which the annual report of 1944 called

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[1031] ARSA 1944, "Exhibit A", SANHS; Green, Vol. II, pp. 213-216, 352; Davis, pp. 70-72.

[1032] Green, Vol. II, pp. 353-354, 459, 463, 594, 617-618. Green points out that even with the acquisition of many machine tools from private contractors who no longer needed them in 1944, the Armory still had to purchase 225 new machines between July and December of that year. Most were simply duplicates of worn machines.

[1033] Ibid, p. 482.

"essential to supply needed production of material and for the establishment of pilot lines to hold the art of small arms manufacture." Great effort went into equipping a revitalized Job Shop with modern machine tools, but primarily versatile ones of the general purpose type.[1034]

The Ordnance Department made small arms research, pilot line production, and an advisory role with contractors the Armory's post-1945 ‘raison d'etre,’ although Springfield also retained the technical responsibility for all of the Army's small arms (Chapters 1 and 2). Mass production of weapons was no longer an intended Springfield mission. By setting up "semi-production lines," the Job Shop could make a wide variety of small arms and associated equipment on demand. More importantly, the very existence of the shop at Springfield would help the Armory "retain the `know-how' for manufacture of many items so that in any future emergency, this knowledge can readily be transmitted to other plants and large scale manufacture inaugurated without delays incident to engineering the item as was necessary at the outset of the present emergency." The goal stated in the 1944 report was to be "The Small Arms Center of the Ordnance Department."[1035]

Setting up the job shop and repairing, overhauling, storing and disposing of machinery were major activities after the war. The Armory had to cut its workforce radically and slow down or halt most of its production. One new development in manufacturing was a better chrome plating facility at the Water Shops in 1946 for .50” caliber barrels. Later this chrome plating technology would prove useful with the .30” caliber barrels of the M14.[1036]

When the Korean War broke out, the Armory had to put its M1 production lines back into operation. At first, there were a number of problems making parts within the tight tolerances that were still a legacy from WWII. Some of the machines were probably no longer up to the demands of mass production, and the officers in charge may not have realized that many WWII parts were not made to official tolerances.[1037]

[1034] ARSA 1944, Section I and IV, SANHS.

[1035] Ibid, Section IV.

[1036] SAHS, 1 January 1946 - 30 June, 1946, pp. 4, 14, 19. Richard Harkins also provided information on chrome plating of rifle barrels.

[1037] SAHS, 1 July 1951 - 31 December 1951, pp. 80-85; SAHS, 1 January - 30 June, 1952, pp. 102-103.

Despite a mission lacking mass production, and the fact that outside contractors would be making most of the M1 rifles that were needed, the Armory made major investments in new machinery for its M1 lines during the Korean War. The historical summary for the first six months of 1952 describes the major changes made to the M1 receiver line:

> M1 Rifle Receiver line has been set up in Bldg. 104, occupying approximately 25,000 sq. ft. of floor space, for 286 machine tools and their related activities, necessary in the production of the Receiver component. With the exception of 38 machine tools, this line has been completed and is being built up to an ultimate capacity of 20,000 pieces per month. This line includes 8 overhead conveyor loops, to facilitate handling the components.[1038]

The line was, of course, much smaller than that used to turn out more than 5,000 receivers a day in 1943. It was, however, more modern and efficient, with expanded use of broaching machines and of conveyors between operations. It went beyond the level of semi-production envisioned for the Armory's future manufacturing role, yet was consistent with the established goals of process development and pilot demonstration. The Armory reported that "this line has been shown in its entirety and in part to various outside contractors, personnel giving them wherever possible any information pertinent to the manufacture of this component."[1039]

After the Korean War, the Armory pulled back once again from mass production and emphasized research, development, pilot line production, and jobbing work. Development work on M1 manufacturing processes continued, probably because of the weapon’s similarity to the experimental semi-automatic rifle that Armory designers were promoting.

In the stocking shop, the Armory in 1955 replaced the Onsrud copying lathes, which had seen "considerable use since 1939," including M1 production for the Korean War, with machines made by J. S. Richardson and Sons in Sheboygan Falls, Wisconsin. In the new Richardson lathes--initially five in number--the workpieces and models were held vertically instead of horizontally, with a saving of "approximately half the floor space." It was hoped to "double the production with one

[1038] SAHS, 1 January 1952 - 30 June 1952, p. 3.

[1039] Ibid. pp. 72-73.

operator running the five machines." At the same time, the production line was revised to eliminate a step (#17) performed by one of the Onsrud routers, by adding that operation to the tasks of one of two new Onsrud shapers. These shapers, which made five cuts each, replaced two that had been making four cuts each.[1040] The new Richardson lathes--an additional four were added later in 1955[1041]--are presumed to be the type pictured four years later in an American Rifleman article on "The Modern Springfield Armory." Acting on three stock blanks at a time, it shaped the stocks "fully" in less than one minute, after which unspecified other machines made the in-letting cuts.[1042] Complete with transparent plastic door and exhaust hose, this triple-threat machine was quite perceptibly an up-ended fourth-generation Blanchard lathe.

Production engineers in 1955 adopted a Mechamatic tumbling machine to eliminate the hand filing for removal of burrs on M1 receivers. It cut the man hours for deburring one hundred receivers from 58.8 by the "old manual method" to 44.4 with the new machine. Obviously, the receiver tumbling experiments in WWII had not been fully successful. It is not clear to the authors that all hand filing was eliminated with the new machine; the reduction in man hours was significant but not startling.[1043]

Modernization of the Forge Shop at the Water Shops complex represented another improvement in production capability. With forging so important to the manufacture of rifle components, the Armory could not stay at the "cutting edge" of small arms technology without modern hammers and the best dies available. In 1955 and 1956, the Forge Shop received sixteen "new air drop hammers."[1044] Broach rifling equipment was in place for both .30" and .50" caliber barrels in 1955, despite some trouble sharpening the broaches. This apparently pioneering application of broach rifling to rifle barrels was an extension of earlier Springfield developments for.45 cal. pistol barrels

[1040] Office memo dated August 8, 1955, from Chief of Hill Shops Branch to Acting Chief, Armory Operations Division, SAHS, 1 January 1955 to 30 June 1955."

[1041] Ibid.

[1042] Walter J. Howe and Col. E. H. Harrison, "The Modern Springfield Armory," p. 25.

[1043] Historical Report of the Hill Shops Branch, p. 3, in SAHS 1 January 1955 - 30 June 1955; Historical Report of the Production Engineering Branch, July-Dec. 1955, p. 2., in same.

[1044] Historical Report of the Factory Branch, p. 2, in SAHS 1 January 195630 June 1956.

and .50” caliber machine gun barrels in World War II.[1045]

N. Making the M14 Rifle, the Last Springfield Rifle

One of the strong arguments for the selection of the M14 rifle was that it was so similar to the M1 that major savings would be possible by using a great deal of M1 tooling. The hopes for re-using M1 tooling turned out to be very optimistic, but the Armory did invest a great deal of effort in setting up a production system that used many of the same machines, though often with new or modified fixtures and cutting tools. With some new equipment and the benefits of experience making the M1, the "mass production processes were completed for all the major components and recommendations for changes in design were compiled" by July, 1955. The shops had turned out by then five hundred examples of the T44E4, which was soon to be officially adopted as the M14 in 1957.

The government intended the M14 to be made by private industry, assisted by the Armory; but the Ordnance Department refused Armory requests to do the thorough engineering study that Springfield's manufacturing specialists considered necessary for mass production. As might be expected, the first two outside contractors (both of whom had made M1 rifles during the Korean War) had more difficulty making the M14 than did the Armory, which soon found itself a major manufacturer of the U. S. Service Rifle once again. However, all three of these makers, including the Armory, were left behind by a firm that had never turned out small arms before. In 1961, TRW joined the effort to make the M14, with few preconceptions about acceptable technology and with a willingness to invest in any modern equipment that could do the job efficiently. TRW, unlike the Armory, had no lines of existing machines and tooling for rifle production, and its goal was to cut cost in the long run with a daring, initial investment in innovative production technology. Its broaching applications, for instance, were far superior to the broaching at the Armory, which had once been such a leader in that technology.[1046]

[1045] Historical Report of the Industrial Division, 1955, Section 25; Thomas Moore and William Goss, "The Springfield Armory," p. 12.

[1046] Ezell, "Search," pp. 249-250; Historical Report of the Production Engineering Branch, p. 3, in SAHS, 1 July 1955 - 31 December 1955; Walter Howe and E.H. Harrison, "The M14 Rifle," pp. 17-22, and "Making the M14 Rifle," pp. 13-20. Ezell, The Great Rifle Controversy, has the best discussion of the contracting of M14 production and the advantages of TRW. Winchester, according to Howe and Harrison, also invested heavily in new equipment, including a great deal of automatic machinery but had trouble getting it all to work properly. They were most successful with automatic woodworking machinery, an area in which the Armory also had good results.

The officers at the Armory tried to keep up with new technology, but put most of their efforts into the experimental equipment and job shop improvements that they saw as the salvation of their facility. The Operations Division reported in 1956 that "The type of manufacture facing the Armory...required a greater degree of skill on the part of the operator than for repetitive manufacture, such as the M1 Rifle, where complex tooling and many special machines are employed." The Armory was unfortunately lacking in sufficient types and sizes of equipment to properly equip its expanding Job Shop.[1047]

The Ordnance Department allowed the Armory to make some purchases of advanced machinery, including a few numerical control machine tools and others which combined gaging with machining processes, but private industry kept moving ahead. Public awareness of the Armory's changed role was limited, even fourteen years after World War II. When American Rifleman ran a story on "The Modern Springfield Armory" in 1959, the authors noted that

> Springfield Armory is no longer a manufacturing arsenal. Surprising as that may seem, it has dropped the mass production of rifles which was long its principle function. Instead, it is responsible for new small arms that are carried through all the stages from development to pilot production. Then full production is done by industry.[1048]

ABBREVIATIONS IN NOTES

ARCO	U.S., Ordnance Department, <u>Annual Report of the Chief of Ordnance to the Secretary of War for the Fiscal Year Ended June 30, ----.</u>
ARSA	Annual Report of Operations at the Springfield Armory. Titles vary, and reports appear in different archival sources, as noted.
RG 156/	Record Group 156, Records of the Office of the Chief of Ordnance, National Archives. Record entry number follows slash.

[1047] Historical Report of the Armory Operations Division, pp. 1-3, in SAHS, 1 January - 30 June 1956.

[1048] Howe and Harrison, "The Modern Springfield Armory," p. 22.

SAHS	Springfield Armory Historical Summary for the Period ----, on file at Springfield Armory National Historic Site. These are semi-annual or annual reports covering the years 1951-1965.
SANHS	Springfield Armory National Historic Site. This refers to material held by the National Park Service at Springfield.
SFSA	Statement of Fabrications, Other Work Done..at National Armory, Springfield, Mass. Titles vary. These records, in RG 156/21, appear to be the only available summaries of annual operations c1865-93.

Chapter 8

RESEARCH AND DEVELOPMENT

Until late in World War II, Springfield Armory's primary mission for the Ordnance Department was the production of high-quality small arms which met department standards of interchangeability and uniformity. In pursuit of this mission, Armory managers and other department officers were committed to the development and stability of the Armory manufacturing system. As we noted in Chapter 2, this commitment made research and development of new designs or materials ancillary to weapons production.[1049] During the first half of the 19th century, Ordnance Department small arms making efforts at experimentation, design, and practical application of new ideas were largely limited to new mechanical and organizational advances discussed in chapters 6 and 7. Research and development can be defined as explicit definition of problems and objectives, organized search for solutions, and sufficient testing and design for practical use of new ideas. The Ordnance Department and Springfield Armory did not become involved in such a framework until the Krag era, and continued to weigh most new weapons designs against possible changes to existing production systems for many decades thereafter.

Until about World War I, Armory researchers and experimenters were usually ordnance officers with simultaneous responsibilities overseeing Armory shops. These men, and other ordnance officers, were at best wary of new weapons designs requiring changes in production, jealously guarding the carefully crafted means of achieving interchangeability against the disruption of major retooling episodes. Superintendent Roswell Lee was highly aware of the relationship between design changes and production problems during the long gestation of interchangeable small arms manufacture. He insisted that adherence to uniform weapons patterns was more important than design changes in search of more perfect models.[1050] This attitude became the approach of later

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[1049] Edward Ezell has noted the long-term connections between an emphasis on production and implications for later Army small arms designs, in "The Search for a Lightweight Rifle" and The Great Rifle Controversy.

[1050] Lee to Senior Officer of the Ordnance Department, November 20, 1817, quoted in Huston, p. 115.

generations of ordnance officers, becoming perhaps more rigid after the Armory had a mature manufacturing system in place. Line and ordnance officer insistence on excellent weapon performance in adverse field conditions also made acceptance of new designs more difficult. In perhaps the most succinct comment on the priority of producing many reliable weapons over fewer but better ones, Army Chief of Staff Gen. Malin Craig is said to have remarked "The best is the enemy of the good" on the eve of World War 11.[1051] As that conflict ended, and the Armory's role in production and procurement shifted fundamentally towards support of private manufacturers, research and development took on far greater importance. After a century's subordination of new designs to existing manufacturing methods, however, post-1945 Armory research results were mixed, and for technical and political reasons required increased adoption of private industrial practices. The fundamental wartime shift towards military reliance on private manufacture, and on industrial or academic research and development, placed the Armory in what became an unsuccessful endgame situation.

The primacy of production at the Armory often had ill effects on the nature and pace of new shoulder arms designs. At the same time, this emphasis evolved into a broad range of technical capabilities which allowed the Armory to evaluate or develop designs across the entire range of small arms. By the end of the 19th century, Springfield Armory was the Army's principal research center for small arms and some related materiel. Achieving this position, which the Armory retained until its closing, took at least seventy years, and only in the early 20th century were sufficient facilities in place to allow for any significant metallurgical research independent of assistance from public and private institutions.

This chapter traces the history of Armory research and development through six periods. Before the Civil War, Springfield shared small arms design responsibilities with Harpers Ferry and with other ordnance officers, during an era of very limited research. The destruction of the Virginia armory in 1861, and the department's increased attention to private breechloading and magazine rifle designs, required more constant research efforts from Springfield. The Armory developed a modest ballistics research capability and became the Army's main testing site for new designs during the second

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[1051] Green et al., The Ordnance Department, pp. 177-8; Weigley, p.416.

period, lasting from the Civil War to the selection of the Krag-Jorgensen rifle. Although limited improvements to Armory rifle designs emerged in this period, there was no formal framework or research staff for planned development. Springfield's failure to produce an acceptable magazine rifle, and subsequent metallurgical, production, and design problems encountered in making the Krag, resulted in a third period of intensive work on magazine rifles followed by early investigations of semi-automatic weapons, c1893-1917. More directed development work, often ordered by the Ordnance Department, done with limited facilities and a continuing lack of research staff, marked this period. After about 1907, more facilities and personnel were used to pursue semi-automatic rifle development from design selection through production engineering. The Armory continued its earlier research and development work on pistols and machine guns through this third period, with the latter responsibility evolving into a new role in aircraft armament development after World War One. Although the thrust of Armory research continued unchanged following that war, important differences in approach emerged from a surge in wartime product testing requirements, and from Ordnance Department recognition that successful designs could not rely on foreign or civilian work, or on the informal tinkering of department personnel. During the fourth period, from about 1917 to 1941, the Armory pursued both product testing and new design work with full-time civilian staff and enlarged laboratory facilities. The more defined identity and importance of research and development in this period helped the Armory survive years of severe funding restrictions. World War II, during which the Armory conducted a large number of tests and projects to address problems with combat weapons, was a critical period of transition. As we outlined in Chapter 2, the Armory's autonomy met increasing Ordnance Department restraints, and its traditional production responsibilities ended. Armory research and development concentrated on traditional small arms projects after the war, in a final sixth period, but these efforts now complemented pilot weapons production in an era of predominantly commercial weapons procurement.

Limited Testing and Design Work at Springfield Armory, c1815-1864

Prior to the beginnings of Ordnance Department responsibility for small arms production in 1815, there was little if any work at American armories which we could now call research or development. All arms makers paid by the national treasury were hard pressed to make acceptable versions of the models derived from French designs. Some of the mechanical efforts at making these models prior to 1815 were experimental, but Springfield Armory's record for this period suggests that all such

work was largely unplanned and incidental to regular production (see Chapter 7). Most design changes, such as Eli Whitney's adoption of the French 1797 musket as a pattern for a state militia musket, were of a similarly decentralized, unplanned, and relatively minor nature.[1052] The only radical new small arms design work in this period were the pistol and musket created by Marine T. Wickham, which the Commissary-General of Purchases promoted for interchangeable manufacture. Evidently designed with little attention as to whether they could be made either interchangeable or in very large numbers, the Wickham models were perhaps the antithesis of later Ordnance Department development work. With the exception of the Krag rifle--approved prior to any production engineering--the department pursued virtually all small arms improvements with close attention to problems of manufacture.

American military small arms development lacked a permanent framework or unified set of facilities during the first five decades of Ordnance Department control of armories. We have discussed the extent to which manufacturing development in this period was largely a product of autonomous efforts by Armory managers, with departmental involvement usually limited to management of funds and encouraging words. In contrast, there was very little work on new weapons designs not conducted by departmental order. Other than occasional, apparently unsolicited, suggestions about design changes by ordnance officers and a few private inventors, work on new designs before 1845 usually followed directions from the Chief of Ordnance. Ordnance Department records maintain this distinction between mechanical development and design work: official correspondence often refers to mechanical or technical modifications, but very few of the letters or reports classified by the department as related to experiments, inventions, or improvements refer to these modifications.[1053] Most of the small number of new design episodes featured temporary groups or formal boards drawn together for the special task at hand. In this framework, the department drew on personnel from both armories, as well as other arsenals and, occasionally, on private contractors. The 1828 inspection of 100 Springfield muskets mentioned in chapter 3, made at Pittsburgh Arsenal to assess interchangeability, was an example of the dispersed, informal quality of antebellum ordnance research. Springfield Armory had no special research status

[1052] Wadsworth to Armstrong, June 6, 1814, Letters.. sent to the Secretary of War, RG 156/5.

[1053] Many patterns in this and the following paragraphs emerge in Ordnance Department registers (c1813-70) of Inventions, etc (R3 156/192), Inventions, Improvements, etc. (Fn 156/193), and Experiments CRS 156/199).

or facilities, although the recognized mechanical capabilities of its staff sometimes warranted selection for specialized tasks.

Congressional hostility to research expenditures until the 1830s hampered Army ballistics and metallurgical development, requiring the somewhat haphazard framework noted previously. The growth of the U.S. Military Academy, after its 1802 birth under President Thomas Jefferson, was an important exception to this pattern. The Academy provided instruction in engineering and French mathematics, and was for many years the only source of trained American engineers. Secretary of War John C. Calhoun's 1817 reorganization of the War Department, and the subsequent appointment of Sylvanus Thayer as Academy superintendent greatly strengthened the institution. Thayer modeled the Academy on the Ecole Polytechnique, despite lack of Congressional support. At this time, most officers with engineering training worked on western exploration projects, or on eastern civil engineering projects such as canals.[1054] Although it is not surprising that the Army did little weapons research or development in this period, the Academy provided basic theory and information on European practice, allowing officers to move into weapons research under more favorable funding circumstances. By 1841, cadet officers received instruction on gunpowder testing, the ballistic pendulum--recently developed into a practical instrument in France--and the rotating disc chronograph, and were expected to know differential and integral calculus. Their course in iron metallurgy was more reliable than most information available in the United States at that time.[1055]

Increasing problems with industrial materials moved Congress towards somewhat more tolerance of research by the mid-1830s. Boiler explosions led to funding for a Franklin Institute study of mechanical properties of iron, during which a testing machine was built and run to make the first American measurements of the strength of iron.[1056] The contemporary establishment of standard weights and measures, under the direction of the U.S. Coast Survey's Ferdinand Hassler, helped

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[1054] Daniel H Calhoun, The American Civil Engineer; Peter M. Malloy, "West Point as America's Ecole Polytechnique;" Russell F. Weigley, History of the United States Army, pp. 124-147.

[1055] Lt. Miner Knowlton, "Notes on Gunpowder, Percussion, Powder, Cannon and Projectiles;" C. Cranz, Textbook on Ballistics, p. 34.

[1056] Walter R. Johnson and Benjamin Reeves, "Report of the committee of the Franklin Institute.. on the explosion of steam boilers..," Jour. Franklin Inst. Vol. 19 (1837), pp. 75-109; Bruce Sinclair, Philadelphia's Philosopher Mechanics.

make that agency the most important federal research arm.[1057] These developments were of potential importance to Ordnance Department research efforts, but had no practical effects on weapons development before 1840.

Aside from its consideration of John Hall's privately-developed breechloader designs,[1058] the Ordnance Department oversaw four major small arms design episodes before a plethora of breechloader models began appearing after c1845: the design of the Model 1816 flintlock musket; a prolonged period of experiments and design alternatives for the Model 1840 flintlock musket; the design of the Model 1841 percussion rifle; and the development of the Model 1842 percussion musket. Each of these episodes was different, reflecting the department's somewhat informal approach and tendency to rely on a few widely-scattered men with sufficient experience and technical abilities.

The earliest episode, beginning immediately after the department gained control over the national armories, was development of the first Army musket model designed for standard--although not interchangeable--manufacture by public and private armories. The basic elements of what became the Model 1816 musket emerged from a meeting in 1815 among Chief of Ordnance Col. Decius Wadsworth, Armory Superintendents Roswell Lee and James Stubblefield, and contractor Eli Whitney. During the next year, Lee and contractors Lemuel Pomeroy and Marine T. Wickham (the latter having recently left government service) submitted additional comments to the department. Although we do not know the relative weight given to these various opinions in final design authorization, the consultation process is of interest because outside contractors were directly involved. With the exception of occasional comments on new models such as that offered by Pomeroy in 1839 and the government's unusual relationship with Hall, the Army generally excluded contractors from direct involvement in weapons design or selection until after the Civil War. This shift probably derives almost entirely from increasing department confidence in the expertise of its own personne1.[1059]

[1057] Hunter Dupree, Science in the Federal Government, p. 52.

[1058] Smith discusses the department and Hall extensively in Harpers Ferry, pp. 189-218.

[1059] Entries 7, 8, 13, 15, 19, and 106, Register of Inventions, RG 156/192.

Development and acceptance of the Model 1840 flintlock musket took about nine years, and was the earliest Army shoulder arm designed entirely by the Ordnance Department, without much input from contractors other than Hall. This process included, perhaps for the first time in Army history, testing of possible prototypes, consideration of alternative designs, preparation of specifications, and explicit consideration of partially interchangeable manufacture. Chief of Ordnance Col. George Bomford sent Lt. Daniel Tyler to France late in 1829, to procure small arms samples and information on French arms production. Tyler was evidently successful, and in 1830 was named the first Chief Inspector of Contract Arms.[1060] By the end of 1830, Bomford instructed Tyler, Lee, and Harpers Ferry Master Armorer Benjamin Moor to consider the merits of French and American muskets, and to recommend a new model. Lee and Moor--in the absence at that time of an experienced superintendent at Harpers Ferry--were the active heads of the two national armories, while Tyler was most directly responsible for contractor conformity with standard weapon designs. Within two years, Lee and Tyler reported on experiments with possible new designs, and with Moor developed specifications for a new model. Col. Benjamin Huger also directed experimental firings with French and American muskets in 1833 at Fort Monroe, Virginia, where the department had previously conducted trials of John Hall's rifles. After Lee's death, Moor continued work on the new design, taking about five years with some help from Hall, who ran his own rifle plant as a contractor at Harpers Ferry Armory.[1061]

With final approval of Moor's musket design at the end of 1838, the Ordnance Department had also completed a process which characterized many of its antebellum small arms research or design episodes. Reacting to perceived inadequacies in standard weapons, department chiefs had designated a board (in this instance, a working group) to identify problems, assess and test acceptable alternative solutions, and make recommendations. These steps originated with department artillery research, and were in this case applied to small arms for the first time. There were apparently no permanent facilities created for small arms tests, which were held at department or other Army posts based on a variety of undocumented factors, such as proximity to Washington

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[1060] Bomford to Tyler, Nov. 30, 1829, and Bomford to the Secretary of War, Jan. 12, 1830, in Benet, ed., A Collection of Annual Reports, vol. I, pp. 185, 202-3.

[1061] Smith, Harpers Ferry, pp. 256-7, 280-81; entries 36, 39, 42, 43, 46, and 51, Registers of Correspondence and Reports Relating to Experiments, vol. I, RG 156/199; entries 16 and 18, Classified Register, Reports of Experiments, vol. 2, RG 156/199.

or convenience for board members. Tests requiring experimental firings were conducted by available, experienced officers or civilian employees, although after the creation of permanent Ordnance Boards in 1839 only department officers directed more formal investigations, sometimes in conjunction with other Army and Navy officers. The full nature of antebellum small arms tests remains unexplored, but it appears that very little special equipment was built or purchased.[1062] Based on board recommendations and, again, the skills and availability of particular individuals, department personnel at the two armories or--after 1848--Frankford Arsenal usually created pre-production working models of preferred designs. There was thus a contrast between evolving, more formal bureaucratic means of controlling and evaluating new designs, and rather informal means of conducting tests and experiments. The department considered few if any designs not created by its own personnel between c1816 and 1845, with the notable exception of John Hall's work.

Selection of the Model 1841 percussion rifle and the Model 1842 percussion musket apparently did not follow the pattern of Ordnance Board oversight, since both models emerged from work by the master armorers and mechanics of the two national armories. Although the department received some reports of work on these models, these episodes appear more like the gradual, autonomous work on mechanization than the explicit search for a new model initiated in 1830.[1063] The extent of departmental supervision or of technical requirements in these cases remains unclear, but was evidently not very formal. Benjamin Moor developed the M1841 rifle concurrent with his work on the M1840 musket, while, at Springfield, Thomas Warner took the lead in adding a percussion lock to this musket for what became the M1842. The work of the master armorer c1836-42 was in some ways transitional between a period of informal, incremental improvements conducted with the blessings of the Chief of Ordnance, and a period beginning c1845 of more consistently rigorous--though hardly unbiased--evaluations by ordnance boards. However, modifying approved models with minor adjustments, based on the initiative of Armory personnel and reactions to such models

[1062] Smith, "Army Ordnance," p. 70. For new components requiring limited tests and no mechanical or metallurgical work by department personnel, boards based in Washington could sometimes make evaluations without recourse to skills available outside Washington, as with the 1845 tests made of the Maynard primer system for percussion locks; see Fuller, Springfield Shoulder Arms, pp. 85-93. Springfield Armory records we have examined indicate no antebellum special research or design facilities other than equipment built for percussion rifle musket development in 1855, discussed below. There is to date no systematic study of small arms testing episodes in this period.

[1063] E.g., entry 79, Registers of Correspondence.. Experiments, vol. 1. Springfield Armory did not produce standard issue Model 1841 rifles, which came instead from Harpers Ferry and a number of private contractors.

from line regiments, remained standard Ordnance Department procedure until 1943. Some of these changes received new model designations, while others--especially those made on the M1--did not. Prior acceptance of the need for percussion weapons, and ongoing development of fully interchangeable standard shoulder arms, probably made the 1841 and 1842 models non-controversial to ordnance officers, although some line officers remained skeptical.[1064]

The Ordnance Department began organized research programs in 1841, focusing on the metallurgy of cannon materials, in response to explosions which were the most serious technical problems faced by the department at that time.[1065] Despite construction of a testing machine and many experiments, there was initially little valuable accomplishment relative to contemporary industrial practice, aside from Rodman's demonstration of the advantage of using a cooled core in casting iron cannon. There was one small arms project in this program, which continued until the Civil War. Maj. Peter V. Hagner experimented with the use of hydrostatic pressure to test musket barrels at Watertown Arsenal in 1844, with W. Wade continuing the work at Springfield Armory in 1846.[1066] The 1846 purchase by the Armory of a hydrostatic proof machine reflects this project.[1067] Hagner showed that faulty welds could be detected prior to machining of the barrel exterior, thereby saving the expense of finishing bad barrels, but as we noted in chapter 7 this research evidently had no effect on Armory manufacturing practice.

The appearance beginning c1845 of many new breechloading, percussion, and repeating shoulder arms systems was a watershed in Army small arms research and development. The framework of Ordnance Department evaluation, testing, and design did not change at this time. In particular, the department only reacted to new designs, but did not actively seek them from outside sources.[1068] There were several major changes in the overall process, however. For the first time, the department

[1064] Although production of Army flintlock weapons ceased in 1842, important line officers like Winfield Scott distrusted percussion arms, and many of the older arms were retained for use until the eve of the Mexican War; see Russell F. Weigley, History of the United States Army, p. 72.

[1065] Smith, "Army Ordnance," p. 72.

[1066] Report of Experiments on the Strength and Other Properties of Metals for Cannon.

[1067] ARSA 1846.

[1068] James A. Huston, The Sinews of War: Army Logistics 1775-1953, p. 188.

had to consider a large number of private and foreign designs, requiring more regular attention by ordnance boards and field installations. Some private inventors used department facilities for their own work, although they bore all costs of such assistance after 1851.[1069] In a few cases--notably the Maynard priming system incorporated in the Model 1855 rifle-musket, and the experimental George Morse breechloader made at Springfield 1858-60--Ordnance Department personnel worked with promising patent designs to assess their suitability for Armory production, and to adapt such designs to Armory manufacturing methods.[1070] The increased volume and complexity of the work required closer and more regular coordination among the major public small arms centers. New ammunition requirements of percussion arms, discussed in chapter 2, led the department to create a third such center in 1848, when Frankford Arsenal in Philadelphia was assigned the task of producing percussion caps. From that date, Frankford personnel were closely involved with design problems, as cartridge and powder issues became major factors in evaluating new weapons.[1071]

The armories evidently had little to do with Ordnance Department tests of new patent design weapons. Congressional appropriations in 1854-55 for purchase and testing of breechloaders led to extensive trials at West Point and Washington Arsenal between 1855 and 1859.[1072] In modifying the Minié ball design and developing a standard service rifle-musket, however, the three government small arms centers were heavily involved, building upon French and British rifle experiments, and on Ordnance Department artillery research which provided a basis for ballistic evaluations. The most important such work in this period included experiments between 1849 and 1855 on cartridges or bullets, rifle barrels, and primer systems, culminating in the development and selection of the Model 1855 rifle-musket specifications based on final experiments made at Springfield. Patent designs other than the Maynard primer played little part in this episode. The work beginning in 1849 included some tests of French and Prussian weapons by department personnel in Washington, but

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[1069] U.S., Ordnance Department, <u>A Collection of Annual Reports...</u>, vol. II, pp. 405-07; Constance M. Green, "History of Springfield Armory" Vol. I, pp. 99-100.

[1070] ARSA 1845-60.

[1071] John Milner Associates, "Historical and Archaeological Survey of Frankford Arsenal," pp. 97-100.

[1072] Huston, p. 157; Classified Register.. of Experiments, vol. 2, entries for 1855-59, RG 156/199; see Claude E. Fuller, <u>The Rifled Musket</u>, for Washington Arsenal test results on the .58” caliber rifle musket.

the major experiments took place at Springfield and Harpers Ferry from 1853 to 1855.[1073] Major Hagner, then commanding Frankford Arsenal, also worked in 1854 with Springfield personnel in the development of a percussion lock and of production gages based on the Maynard design. Hagner's work included tests and specifications for main spring tension. Much of the Frankford-Springfield work evidently proceeded at the discretion of arsenal commandants, to achieve technical solutions to design problems.[1074]

Springfield Armory research capability in this period remained very limited for most purposes. In 1838, for example, "Laboratory Tools" included eighty-two brooms, two copper ramrods, two pulverizing mortars, two funnels, and various jugs. Other equipment in that year with possible research applications included a case of "mathematical instruments," two platform balances, two parallel rules, five sieves, ten thermometers, and a mortar eprouvette for testing gunpowder.[1075] Although Armory technical facilities did not change much until after the Civil War, making Springfield one among several research centers, the 1850s work probably made the Armory the most versatile Ordnance Department installation for manufacture and testing of small arms design prototypes.

Work at Harpers Ferry, directed by Acting Master Armorer, James Burton, Lt. James Benton, and Commandant, Col. Benjamin Huger, successfully modified the Minié ball and established the desirability of rifled barrels for all service weapons. These experiments included making ten differently-grooved rifle barrels, of .54 and .60 caliber, and building a fixed firing rest. Following the 1853-54 Harpers Ferry experiments, the department sent Benton to Springfield in 1855. Benton had been Hagner's junior officer at Frankford, and participated in the work on the new percussion lock. His assignment at Springfield was to address four questions: the best means of rifling existing smoothbore arms; whether reduced caliber for new weapons was desirable; whether a reduced cali-

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[1073] Entry 60, Classified Register of Inventions.. received, RG 156/193; entry 42, Classified Register, Reports of Experiments, vol. 2, RG 156/199; Officers of the Ordnance Department, Reports of Experiments with Small Arms for the Military Service; Smith, "Army Ordnance," p. 73. As suggested by Smith, the mid-1840s artillery research of Capt. Alfred Mordecai (1804-87) was probably an important step in the growth of Army small arms ballistics testing; Mordecai did some of the earliest testing of French muskets with Minié balls in 1849-50.

[1074] Green, "Springfield Armory," Vol. I, pp. 77, 101; John Milner Associates, pp. 97-101.

[1075] Springfield Armory, "Inventory... on hand.. December 31, 1838." SANHS.

ber could be made uniform for all small arms; and the best form of cavity for the Harpers Ferry bullet. For the 1855 tests, master mechanic Cyrus Buckland directed the making of twenty-eight rifle, four carbine, and four pistol barrels, with four different calibers between .54 and .69, and with about two dozen varieties of rifling. Buckland and Benton evidently designed and built a fixed rest or 'firing machine' for these tests, probably different from the device built at Harpers Ferry. As with the Harpers Ferry tests, Benton's Springfield work involved firing at large targets, and measuring deviations from the centers. His tests and recommendations proved to be important, as they led directly to selection of .58" caliber as the new service standard, with specific rifling and barrel length specifications.[1076] The 1853-55 test methods were not innovative, relative to contemporary French ballistics testing methods, but the Armory's technical capabilities provided what was probably the most extensive array of experimental shoulder arm components produced for the antebellum Army. Whether the Armory would have gradually become the Army's chief center for small arms development is moot, since the Civil War suddenly made Armory resources unique.

The Center of the Search for New Weapons, c1864-1893

By the middle of the Civil War, the Ordnance Department's gradual approach to introducing standard issue breechloaders was a matter of serious concern to politicians and some Army line officers. Department personnel preferred designs and production methods as similar to existing ones as possible. Despite extensive pre-war tests of patent weapons, and private solutions to some earlier design problems, the department's approach until 1864 appears primarily to have been reliance on inspired tinkering and testing by department personnel, similar to the informal work which led to the 1841 rifle and 1842 musket. Springfield master armorer Erskine Allin began work on breechloader designs by 1862, probably on his own initiative, and rather informal work by department employees and officers remained one of two principal approaches to new designs until World War I.[1077]

Another approach was solicitation and testing of private designs, in response to the general failure of departmental tinkering. Department and other Army personnel made dozens of proposed design changes in the generation after the Civil War, none of which solved the Army's magazine rifle

[1076] Officers of the Ordnance Department, Experiments, pp. 11-49, 75-93.

[1077] Entries 235-6, 379, Registers.. Relating to Experiments, vol. 1; entries 198-9, Classified Register.. of Experiments, vol. 2.

problem. Assessing private designs began in earnest in 1864 with a year-long series of tests at Springfield of breechloading carbines.[1078] Unlike the more sporadic antebellum department responses to private designs, there was almost constant testing of patent rifles as well as department designs between 1864 and 1893, a period during which seven Ordnance Boards wrestled with rifle design selection.

Throughout this period, and into the 20th century, the department relied only on these two approaches, which amounted essentially to a willingness to test what was available. There was no development of specifications for small arms designs, with subsequent response by inventors or entrepreneurs. Rather, the department sometimes invited submittal of models within general arms classes, and then decided whether the models would meet military needs, based on officer opinions and the results of tests for endurance, accuracy, and rapidity of fire. Progress in military arms designs for the Army was almost certainly slowed as a result, especially when coupled with the emphasis placed on existing production methods. This lack of development became an increasing concern as private American and European arms makers continued to churn out tens of thousands of new military small arms with dozens of workable designs.

Except for some tests made at other arsenals c1867-70, virtually all tests of possible military shoulder arms occurred at Springfield until the very late 19th century.[1079] Same of this centralization resulted from the absence of other national armories, but James Benton's leadership was probably critical in making Springfield Armory the principal center for small arms experimentation. By this time an Army major, Benton commanded the Springfield Armory from 1868 until his death in August 1881, and directed or oversaw hundreds of tests and experiments. His long involvement in small arms development included design of many exterior ballistics[1080] testing devices, including an electromagnetic chronograph he built on French principles in 1859 when serving as an instructor at West Point, and other instruments developed during his command of the Armory.[1081] We have seen

[1078] Entries 390-512 (not inclusive), Registers.. Relating to Experiments, vol. 1.

[1079] Reports and Proceedings of Board of Officers 1864-1905, RG 156/1386.

[1080] Exterior ballistics pertains to the study of projectile behavior outside the weapon being fired.

[1081] Charles B. Norton, American Inventions and Improvements in Breech-Loading Firearms..., pp. 186-9; Crantz, p. 64; ARSA 1871-78; SFSA 1880.

no evidence of Ordnance Department policy or programs for establishment of research facilities at this time, and at present we must assume that the initiative of individual officers like Benton was paramount in developing such facilities.

Beginning about 1871, Benton acquired or built enough testing equipment to give the Armory, and the Ordnance Department, a specialized capability in small arms testing for the first time, setting up the equipment in a new firing house built 1872-73 in Federal Square. Benton enlarged the firing house in 1877, improving its firing stations and targets after about five years of regular tests, purchases, and fabrication of ballistics testing equipment. The firing house was removed from Federal Square in 1887, as planning for the new industrial complex there began.[1082] Although much of the Armory's laboratory apparatus in this period was not very different from the equipment noted for 1838, the addition of ballistic pendulums, chronoscopes, galvanic batteries, densimeters, and a transit shows that Benton and his officers were capable of measuring bullet velocities and rifle recoil. By 1880, copper purchased for pressure gages suggest use of crusher gages for measurement of chamber pressure. Benton's facility, although probably no more advanced than those in same commercial or foreign military armories, gave the Armory a significant capability in ballistics research, allowing for a relatively wide range of tests on small arms, ammunition, ordnance materials, and occasionally devices for other government agencies. By the mid-1870s, the Armory regularly tested rifles, pistols, and Gatling guns, making it at least the de facto small arms center for Army ordnance, and provided ballistics testing equipment to other Army posts and possibly to private arms makers as well.[1083]

Contemporary development of Frankford Arsenal laboratories provided a comparable capability in ammunition experimentation, but both arsenals did a variety of sometimes overlapping experiments in the informal climate of Army research and development.[1084] Springfield tested many

[1082] SFSA 1887.

[1083] SFSA 1871-78; SFSA 1880-91; U.S., Congress, Senate, ...the cost of manufactures at the National Armory..., pp. 9-15; letters, Henry Brewer to Brig. Gen. C. L'H. Ruggles, Aug. 14, 1929, and Ruggles to Brewer, Aug. 16, 1929, SANHS. We are indebted to SANHS curator Stuart Vogt for showing us the latter items, which with associated notes suggest that Winchester Repeating Arms Company may have obtained a Benton chronograph from the Armory before 1885.

[1084] John Milner Associates, pp. 121-22.

experimental cartridges and powder samples through the 1870s and 1880s. The Ordnance Department did not begin to assign formal, specific research missions to its arsenals until the 1890s. While the manufacturing arsenals each had a recognized range of expertise, departmental convenience and the individual skills of the department's limited officer corps continued to determine the location of many tests. In addition to testing the full range of small arms, Springfield occasionally assessed rifle cleaning materials, entrenching tools, lantern lighting apparatus, and lubricating oils. The best known foray away from rifle development was the 1877 invention of the Lyle gun, a marine rescue apparatus for the U.S. Life-Saving Service, designed by and named for an Armory officer.[1085]

Individual interests also apparently dictated the nature of same tests. Evaluation, acquisition, and construction of ballistics testing devices disappears from records of Armory experiments after Benton's death until about 1907, and much of the work done c1870-90 involved tests of small arms improvements developed by Armory officers. Ordnance Department instructions initiated the most important series of small arms tests, and may account for more Armory experimental work than suggested by annual reports.[1086] The slow pace and limited funding of Ordnance Department activity after the Civil War, discussed in chapter 2, suggests, however, that the Armory firing house was available for miscellaneous or personal projects more often than not. Staff officers, and occasionally the commanding officer, acted as an informal research staff, either at individual discretion or under orders. There is no indication in Armory records of civilian personnel engaged in experimentation during this period, although civilians and Armory Detachment enlisted men may well have assisted in test firings, and the master armorer was heavily involved in breechloader "trapdoor" rifle development. As noted in chapter 6, staff officers had no specific shop assignments at this time, and officers conducted or directed all experiments attributed to individuals in annual reports.[1087]

Armory participation in the rather uneven search for acceptable breechloading and magazine rifles was clearly the most important research activity c1864-93, even if formal tests made for ordnance

[1085] SFSA 1871-91.

[1086] We have not pursued original correspondence on this point.

[1087] Ibid.

boards did not take up very much time in that period. Initial Ordnance Department selection of a breechloading rifle was an unsatisfactory, somewhat mystifying process, leading to temporary solutions requiring immediate alteration. Because of the large numbers of stockpiled rifle-muskets produced for anticipated Civil War use, the department first looked for ways of converting these weapons into breechloaders. Armory personnel had been working on possible conversion models for several years before a board under Maj. T.T.S. Laidley, the Armory commandant, tested 65 conversion designs in 1865, including many private models. Although the Laidley board reached no specific recommendations on new models, Chief of Ordnance Alexander B. Dyer ordered a small number of converted rifles based on one of the tested designs, presented by Master Armorer, Erskine Allin. This Model 1865 rifle, retaining most elements of the rifle-musket except a new loading mechanism and rim-fire ammunition, went through two model changes in three years, including changes in caliber, barrel manufacture, and loading mechanism, following the recommendations of an 1866 Ordnance Board under Maj. Gen. Winfield S. Hancock. Armory personnel were largely responsible for all three models, which after 1868 were still regarded as temporary, despite the fact that the Model 1868 was essentially a new, unconverted rifle. After additional experiments and tests on Springfield and patent products, and the issuance of a fourth model, the 1870 carbine, Congress reacted to the plethora of breechloading systems in service by passing a law in 1872 establishing an Ordnance Board to select a single model for exclusive manufacture. Under Brig. Gen. Alfred H. Terry, the board of line and ordnance officers evaluated ninety-six Ordnance Department and private patent designs for breechloading rifles or carbines, including sixteen magazine or repeating models, plus another nine foreign arms. Based on their 1873 recommendation to the Chief of Ordnance, a modified Springfield design using a .45/70 cartridge became the standard Army rifle and carbine for twenty years.[1088]

At Dyer's direction and under Benton's leadership, the Armory began experimenting with magazine rifles as early as 1870, concurrent with work on single-shot breechloaders.[1089] Many of the

[1088] Dyer to Stanton, Nov. 21, 1865 and July 16, 1867, in U.S., Ordnance Department, A Collection of Ordnance Reports and Other Important Papers, Vol. IV, pp. 897-904; Benton to Dyer, Nov. 23, 1870, RG 156/21; ARC) 1873, pp. 48-9; James E. Hicks, Notes on United States Ordnance, vol. I, pp. 901. On the Springfield single-loading rifles and carbines, see M. D. Waite and B. D. Ernst, Trapdoor Springfield.

[1089] Alexander Dyer served as Springfield Armory commandant for over three years just prior to his appointment as Chief of Ordnance in 1864, and oversaw the extraordinary Armory plant expansion during the Civil War (see chapter 4). His strong interest in small arms improvements included personal development of at least one model rifle-musket, and extensive involvement in Ordnance Department breechloader selection; see Register of Inventions, Vol. I, entry 453, RG

magazine arms tested under the Terry board were modifications of Springfield rifles developed by ordnance officers, or attempts by department personnel to adapt patent magazine systems to such rifles. The Terry board report recommended field trials of a magazine-carbine "...made upon the Ward-Burton system at the Springfield Armory." The Chief of Ordnance had to reject this suggestion, citing the 1872 law requiring standardization of all small-arms. This act effectively halted nearly all department work on magazine arms for about five years, except for models created by a few ordnance officers, because experiments with patented designs required appropriations to purchase patent rights and sometimes the personal expertise of private inventors.[1090]

Renewed Congressional interest in magazine rifles after "Custer's Last Stand" led an 1878 Ordnance Department board to examine twenty-nine weapons, selecting the Hotchkiss rifle for limited manufacture and experimentation at Springfield. B.B. Hotchkiss had demonstrated his bolt-action rifle, with magazine in the butt, at the 1876 Centennial exhibition in Philadelphia. Winchester Repeating Arms quickly bought his patent rights and included a rifle of his design in the four they submitted for the 1878 review. After manufacture of about 4,600 Hotchkiss rifles in 1878-79, trials proved this weapon unacceptable for military purposes and by 1881 Congress restarted the search with new funds for patent purchase, development, and manufacture. An 1882 Ordnance Board reviewed forty magazine guns and chose three systems with detachable or fixed magazines for trials in the hands of troops: the Hotchkiss, the Remington-Lee, and the Chaffee-Reese. Based on trials in 1884-85, the Ordnance Department concluded in 1886 that the Remington-Lee (a rifle of turn bolt action with a centrally located magazine to the rear of the barrel) was the best magazine rifle available, but still not as good a military weapon as the single-shot Springfield. Following these two prolonged episodes, Congress ceased further appropriations for magazine arm production until the department could find something acceptable.[1091]

Springfield Armory was the principal test site for the final magazine rifle board tests in 1889-90 and

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156/192.

[1090] ARCO 1873, pp. 48-9; SFSA 1870-75.

[1091] ARCO 1878-87; Philip B. Sharpe, The Rifle in America, pp. 235-236, 323324; Norton, Breech-Loading Firearms, pp. 79, 169, 171; Donald Featherstone, Weapons & Equipment of the Victorian Soldier, pp. 26-32. The Lee magazine system, patented in 1879, was to be the inspiration for the standard military rifles of England from 1888 through World War II.

1893. Selection of the Krag-Jorgensen rifle in 1891 was a tacit rebuff to a generation of Army small arms development centered at the Armory, where about 30 rifles from private or officer sources were tested c1871-91 on a generally informal basis, in addition to the accepted modifications of the trapdoor service rifles, and the nearly 200 rifles tested for ordnance boards. It is probably no coincidence that the firing house and laboratory established by James Benton was designated the Experimental Department around 1891, just as the Ordnance Department accepted a model based on a foreign design.[1092] Although there were no immediate changes in the organization of Armory research and development, Springfield's assignment to produce the Krag began a period of intensive, prolonged research into all aspects of magazine rifle design and materials.

Magazine and Early Semi-Automatic Rifles, c1893-1907

Once the Krag rifle was selected and minor modifications made in its design for the Army, Springfield Armory focused on achieving full production of the new weapon. The Chief of Ordnance was impatient with delays, and had little tolerance for excuses from Col. Alfred Mordecai, the Armory commandant. One of Mordecai's most serious difficulties was selecting the right steel for the new .30" caliber Krag rifle barrel. Good records of previous tests and of experience with steel contractors would have been very helpful, but Mordecai claimed the historical data inadequate as he compiled information from the 1870s and 1880s.[1093] This lack of previous information probably reflects the virtual absence of Armory attention to new gun barrel materials after selection of the Model 1873 trapdoor, as well as the absence of a permanent research or testing facility with systematic record-keeping.[1094] The Colonel was essentially beginning his metals search ***de novo***. In the fall of 1892, he told steel suppliers: "A metal is required that is not readily acted upon by the gases, from the new powders now coming into use." The Armory wanted to assess chromium, nickel, and carbon steels in testing machines--which it lacked at that time. Mordecai listed the minimum levels that Armory technicians required for tensile strength, elastic limit, and

[1092] Derwent S. Whittlesey, "The Springfield Armory," chapter 7, which asserts that the Experimental Department began in April 1891. Nothing in our data notes this transition, which tends to confirm our impression that lack of formal research organization continued for some years, even if a paper department was created.

[1093] Mordecai to Flagler, June 10, 1892, RG 156/1354.

[1094] For discussion of the value of a good system of data storage and retrieval for research see Green, "History of Springfield Armory", Vol. II, book I, p.34.

elongation.[1095]

The search for an acceptable barrel steel dominated Armory research efforts from 1893 to 1900, essentially adding another informal research section to the small arms testing conducted by the Experimental Department. Springfield was poorly suited for metallurgical work in 1893, when steel tests began, and evidently did not begin to acquire any special equipment for metals tests until about 1897. Instead, Armory officers developed a workable alliance between Army and private industrial facilities, to solve what was probably regarded, at least initially, as a temporary bottleneck to production. Watertown Arsenal analyzed chemical and physical properties on the Army's most sophisticated testing equipment, and private steelmakers anxious to receive barrel steel contracts apparently provided information on steel sample components. Some companies, such as Bethlehem Iron Company, conducted tests and other experiments at the Armory's request. At the Armory Watershops, officers and foremen directed practical tests on steel samples and completed barrels, "with the tools and machines now used," including rolling, annealing, and machining. Firing tests with high pressure cartridges more or less completed the techniques available to Armory officers through most of the steel search period. Research and production went hand-in-hand in those shops. In the Armory reports for 1900, there was a clear division between the experimental firings on the Hill, which were under the officer in charge of the Hill Shops, and the research done with metals, which was the responsibility of the officer in charge of the Water Shops; this division probably pertained from the mid 1890s. The work at the Armory demonstrated a concern with manufacturing as well as operational requirements.[1096]

Results of early testing appeared in the published reports of the Chief of Ordnance for 1892 and 1893, but Brig. Gen. Daniel W. Flagler was not pleased with the amount of time taken to find suitable steel for barrels. He told Mordecai that it was fine to try to find steel "that is fully satisfactory for the purpose... But the urgency of undertaking at once, the construction of the new rifle for service renders it imperative to now select from the steels which have been tried the one which you consider best adapted for the purpose and proceed with the manufacture of the .30”

[1095] Mordecai to a list of suppliers, September 19, 1892, RG 156/1351.

[1096] ARCO 1892, p. 329, 1893, pp. 202-4, 1894, pp. 55-6, 1895, pp. 69-73, 1896, pp. 56-60, 1897, pp. 73-4, 1900, Appendices 9 and 11; Mordecai to Flagler, December 30, 1892, RG 156/1354.

caliber rifles." As was to be the case in the development and improvement of many weapons in the next century, Mordecai was asked to make a quick choice based on preliminary research and to keep testing after production was underway. Mordecai replied that he had steel [carbon steel] that "will answer for the present."[1097] Further testing of alternative alloys and of various steels made with the available processes of the time (i.e. Bessemer, open hearth, and crucible) continued at the Armory and elsewhere throughout the manufacturing history of the Krag, after the initial use of crucible steel. Practical experiments with the machinability of nickel steel were unsuccessful, and carbon steel continued as the preferred barrel material. Bessemer steel was accepted in 1897, based heavily on tests done by Bethlehem Iron Company, although there was a brief unsuccessful shift to open hearth steel in 1899-1900.[1098]

An article in Scientific American in 1899 gave a public explanation of the chemical content and physical characteristics that the Armory sought in its steel barrel blanks and mentioned testing procedures to insure compliance with Armory specifications. In addition to the ongoing program of chemical and physical tests, some outside and some at the government facility, the Armory reserved the right to send inspectors to "witness each operation in manufacturing the steel." After the barrels were formed in the Water Shops, every one was "tested to a pressure of 70,000 pounds to the square inch in the cartridge chamber, and ten or more barrels made from each new lot of steel delivered are subjected to a special test of 100,000 pounds to the square inch." This final test subjected barrels to two and a half times the existing service requirement.[1099]

The heat-dependent research that went on at the Water Shops must have been somewhat inaccurate and unreliable until the late 1890s. Many heat treating, case hardening, and deformation (rolling and forging) processes in rifle-making apparently required workers to make temperature judgments by eye, a less than precise method. Despite some shop floor success with a sharp reduction in barrel rolling temperatures in 1898,[1100] a lot of guesswork was still involved with heat determinations. In

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[1097] Flagler to Mordecai, Oct. 11, 1893, RG 156/1365; Mordecai to Flagler, Oct. 19, 1893, RG 156/1354.

[1098] ARCO 1895, pp. 69-73, 1897, pp. 73-81, 1900, pp. 115-16.

[1099] Scientific American, "Manufacture of Krag-Jorgensen rifles at the Springfield Armory - I."

[1100] ARCO 1898, p. 85.

1900, the Armory bought two pyrometers, which would have allowed much better control of temperatures. The best temperatures for various operations could be determined by testing, and most importantly, good results could then be attained with greater consistency. The Commanding Officer of the Armory reported that there had always been "uncertainty as to the heats used in the different operations," but with the new pyrometers, "heats have been regulated with very satisfactory results as to uniformity of product."[1101]

As we discussed in Chapter 3, the Army needed uniformity in the physical characteristics of interchangeable components. Armory research and scientific apparatus in this case, as in most others of the period, was in the service of production. The most important piece of equipment obtained in this period, at the end of the steel search, was a Riehle testing machine with 50,000-pound capacity. Purchased in 1900, it allowed for rapid determination of tensile, compression, and ductility properties of purchased steel, to control the quality of accepted material and to help achieve uniformity of manufactured components. Most necessary steel tests were probably done in-house after the purchase of this machine. These tentative beginnings at prompt, accurate, quantifiable materials controls remained relatively static until the demands of World War I.[1102]

As the Armory resolved steel and other manufacturing problems associated with the Krag rifle, research emphasis tended to shift to the Hill, where the Experimental Department continued its tests on proposed small arms designs and proof testing Armory products. By 1900, this department was an adjunct to Hill Shops manufacturing, under the command of the same officer assigned to oversee the Hill Shops, as the intensity of work on new rifle designs had diminished between 1891 and the Spanish-American War. Firing tests on each rifle, and perhaps for most other tests of newly manufactured weapons, were conducted in a testing room added to the south end of the new Federal Square machine shop in 1893. For accuracy tests, and for other tests of new small arms designs requiring longer ranges, facilities were evidently created elsewhere on the Hill, including above some storehouse space. Annual reports do not indicate any dramatic changes in small arms research procedures during the 1890s, and, along with payroll records, continue to suggest an absence of any civilian research staff. When necessary, civilian employees were detailed to make firing or accuracy

[1101] ARCO 1900, p. 104.

[1102] ARCO 1900, p. 104.

tests of newly manufactured arms. There is no evidence that the basic organization of Armory research--with tests managed or conducted by a small staff of officers with other responsibilities, assisted by production workers--changed before World War I.[1103]

The Armory for many years had been required to take time away from its own research efforts, to evaluate ideas and products submitted by outsiders, often without any solicitation or official encouragement. Selection of a foreign design for the first magazine rifle stimulated a surge of "patriotic" invention, which the U. S. Army was not in a position to discourage, but which was a distasteful burden for the Springfield Armory. The Chief of Ordnance ordered Colonel Mordecai to accept weapons, models, and even plans for small arms during the intense tooling up period for the Krag. If there was potential in a submission, the commanding officer was to "aid the inventor in perfecting his arm." Mordecai, under terrible pressure to get the Krag in production, was understandably resistant to this order and apparently did his best to reject inventors' ideas immediately.[1104]

The Armory's researchers were never very receptive to small arms designs that came from outside inventors. The widely-acclaimed design of the next service rifle, the Model 1903, developed between 1899 and 1902 and included many borrowed elements from the Krag and the Mauser, yet the final weapon had a distinct form and identity of its own. Although modified several times between 1903 and 1906, the new Springfield rifle was the Armory's most successful design to emerge from the informal framework of Experimental Department work. Even as the production of the new rifle began, experimentation was underway at Springfield Armory on the next generation of infantry rifles: self-loading, or semiautomatic weapons. The fully automatic machine guns of the late nineteenth-century had shown that it was theoretically possible to make a rifle load itself. Semi-automatic pistols, which fired at each squeeze of the trigger, were in use by 1900, and private

[1103] e.g., Post Order no. 39, August 30, 1892, in Springfield Armory Post Orders 1890-1898, SANHS. Armory payroll records in the National Archives, which are unavailable after 1898, show no civilian personnel paid for experimental work. Green claims that an officer with a small staff of civilians was detailed to experimental work around 1900, in "Springfield Armory Ordnance Research," SANHS; no primary data we have seen supports this claim. (She is not listed as the author of this unpublished manuscript, but since it bears her unmistakable imprint and was written during the period of her voluminous writings on the Armory, we believe she is the author).

[1104] Flagler to Mordecai, 18 October, 1892, RG 156/1365. See also RG 156/1354 for examples of immediate rejection by Mordecai in 1893.

inventors were already designing their own versions of a semi-automatic rifle for possible adoption by the military. The full implications of the machine gun were not yet apparent, but the infantry would need same help in overcoming the advantage that fully automatic weapons gave troops in defensive positions.[1105]

The bolt-action rifles in general use by the major armies of the world in the early twentieth century had certain disadvantages. The rapid operation of a bolt action rifle required manual dexterity and practice; the military had to spend a great deal of time training men to work their bolt actions properly. Natural "left handers" had additional problems and needed even more practice. Often, the manual operation caused even the best soldiers to lose sight of their targets between shots. A soldier's rate of accurate fire was limited by his ability to operate the bolt and to reacquire a good "sight picture" after each shot.[1106]

At Springfield Armory, the search for a semi-automatic rifle apparently began in 1900. An American officer in Germany alerted the Ordnance Department to European interest in semi-automatic small arms and, in particular, to Danish progress in the development of such a weapon. Armory commandant Lt. Col. Frank Phipps expressed interest in the concept and requested that the Ordnance Department acquire European models for examination. Formal testing of the Bergmann Combination Pistol and Carbine from Germany ended with rejection in 1901. An American firm, the Buescher Manufacturing Co., submitted blueprints for a rifle in 1901, but Armory officers considered the design unsuitable. Springfield staff were also working on their own solutions to the problem of self-loading. In 1902, a mechanical draftsman named J. L. Murphy submitted a drawing of a rifle as the basis for a research effort. Capt. John Thompson (soon to be famous for his Tommy gun) added his ideas for a telescopic bolt, while he was stationed at the Armory. In 1903, a Danish officer, Lt. Schouboe, sent a model which was finally rejected in 1911. There was no authorization to build a Springfield-designed model of a semi-automatic rifle until late in 1905, when Lt. Wilford

[1105] Edward C. Ezell, "The Search For a Lightweight Rifle," pp.40-42; Melvin M. Johnson, Jr. and Charles T. Haven, Automatic Arms, pp. 29-30, 51; Philip Sharpe, The Rifle in America, p. 513; John Ellis, The Social History of the Machine Gun, pp. 71, 123.

[1106] Ezell, "Search," p. 40; Johnson and Haven, p. 64: author Malone's personal experience with bolt-action and semi-automatic rifles.

Hawkins was placed in charge of this important project. He began with Murphy's modified rifle and moved on to one of his own, with no success. By 1908, the Experimental Department seems to have became more active in this and other projects and was acquiring better equipment for its expanding scope of work, including two new velocity measuring instruments, an improved firing gallery, and a large inspection room. Yet slow progress characterized these early years of experimentation and development.[1107]

The new Chief of Ordnance, Maj. Gen. William Crozier, had claimed in his annual report of 1902 that semi-automatic "muskets" were under study, but "no rifle of the class has been presented to this department for examination and tests, although its willingness to take the subject up has been signified whenever the occasion has been offered." This public statement is accurate, because the only true submittal had been a combination pistol and carbine, not a "musket." Crozier did have some serious reservations about semi-automatic rifles, believing these weapons raised both tactical and mechanical questions. He was only considering "the possible desirability of the substitution of a semi-automatic musket for the hand-operated magazine rifle."[1108]

By about 1907, Crozier was evidently more sanguine about new design possibilities. His office asked Springfield Armory to draw up basic specifications for a new semi-automatic rifle in 1909. This was apparently the first time the department took such an approach in small arms development, but most Armory effort went into modifications of the M1903 rifle that might make it self-loading. Even the 1909 pamphlet of these specifications, <u>The Design of a Semi-Automatic Rifle Should Embody the Following Features</u>, said that the department would consider designs that modified or adapted the existing service rifle and would accept a magazine capacity of only five cartridges in such converted designs (compared with at least eight cartridges for completely new rifles). A semi-automatic version of the standard rifle would, of course, have saved a great deal of expensive retooling. In 1910, the annual report of the Chief of Ordnance included the positive statement that the department was "endeavoring to develop or procure a semi-automatic shoulder rifle which will prove satisfactory as a military weapon." The work was still "in an experimental state, but there is

[1107] ARCO 1908, p. 59; Davis, "U. S. Rifle Caliber .30, Ml," SANHS, pp. 1-10. Ezell, <u>Great Rifle</u>, pp. 10, 13, 17-18, provides a valuable list of "Self-Loading Rifles Tested by the US Army 1901-17."

[1108] ARCO 1902, p. 7, 1903, p. 12.

some promise of ultimate success." By then a number of semiautomatic hunting rifles were in civilian hands. Despite a slight shift in emphasis, department pursuit of new rifle designs remained leisurely, and retained the practice of awaiting designs from private inventors.[1109]

The search for a semi-automatic pistol was much less difficult. It is, in fact, easier to create a self-loading pistol than a high-powered semi-automatic rifle. Testing of revolvers and semi-automatic pistols in 1911 led to the selection of the Colt .45 caliber semi-automatic, which was based on an earlier design by John Browning. This rugged and relatively powerful handgun and its cartridge underwent further testing and evaluation at the Armory in the following year. Although Colt and other contractors produced the vast majority of these short-recoil operated pistols, Springfield Armory also made them at various times.[1110]

Testing of semi-automatic rifles designed by members of the Ordnance Department and by private inventors increased in the last years before World War I. In 1913, Rock Island Arsenal submitted its own conversion of the Model 1903 rifle for testing at Springfield. Officers at the Massachusetts facility, who were having poor luck with their own conversions and new designs, were probably quite pleased when the Illinois product suffered a broken bolt after only two test shots.[1111] During the war, attention naturally shifted to the urgent need for greater production of existing bolt action rifles, both the standard 1903 Springfield and the Enfield. Nevertheless, the Ordnance Department did develop a secret semi-automatic mechanism which converted the 1903 Springfield into a self-loading rifle. This attachment, known as a "Pederson Device," replaced the bolt of the rifle and allowed it to fire a modified, pistol-type cartridge in a semi-automatic operation. John D. Pedersen, a civilian inventor, had developed a straight blow-back action and a forty-round, detachable magazine. The Ordnance Department manufactured large numbers of these "Pederson Devices" during the war but never issued them to the troops, instead keeping these devices secret and destroying almost every example in the 1920s.[1112]

[1109] Davis, pp. 6-8; ARCO 1910, p. 595; Sharpe, pp. 513-514; Johnson and Haven, pp. 53-56.

[1110] ARCO 1911, p. 30 and 1912, p. 45; Flayderman, p. 108; Johnson and Haven, p. 93.

[1111] Davis, pp. 11-14; Ezell, Great Rifle, pp. 17-19.

[1112] Sharpe, pp. 532-533; Johnson and Haven, pp. 52-53. Ezell, Great Rifle, does not give attention to Pederson's device. Sharpe ties this all in with the later development of the semi-automatic carbine. It makes a

Growth of Full-Time Research Facilities, and M1 Development, c1917-1941

Although the Ordnance Department concentrated primarily on production of standard weapons and equipment during World War I, that conflict was important in the eventual formation of an effective research establishment for the military. The war showed how not to do research, while at the same time offering a hint of the vast potential of scientific knowledge and technical experimentation for the development of future weapons. American research efforts contributed very little to the war effort, and much of the weaponry used by American forces was derived or borrowed from European sources. Research and development takes time, even under the best of conditions, but American participation in the war was very brief. Organizing research efforts at the last minute, after trying to maintain an image of neutrality, the U.S. government and its military branches were horribly unprepared for the demands of a major scientific effort. There was some successful work done on poison gas, submarines, optical gas, hydrophones, mines, tanks, and aircraft armament, but most of the research done for the benefit of the military was uncoordinated and unproductive. As Hunter Dupree has concluded in his seminal work Science in the Federal Government:

> The great drawback to the civilian establishment was its orientation around peacetime problems, the difficulty of dropping its usual work, and above all the lack of leadership from the military in the selection and priority of problems. No administrative mechanism existed to mobilize the government's scientific establishment for war.[1113]

The idea that America's civilian inventors, acting at random and on their own initiative, could conceive and help develop a wealth of useful weapons in a national emergency was finally discredited by the experience of World War I, although lingering vestiges of this optimistic assumption persisted through World War II. The Naval Consulting Board, chaired by inventor Thomas Edison, screened 110,000 suggestions and found 110 worthy of detailed study, only one of which reached production. Many of the nation's best researchers, who had begun working at government request on projects of clear importance to the war effort, were pulled from their universities or commercial laboratories and commissioned for service in the military, where they

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logical connection.

[1113] Hunter Dupree, Science in the Federal Government, pp. 301-325. See also the classic study of the World War I aerial weapon, I. B. Holley, Jr., Ideas and Weapons, pp. 16-19, 103-117.

were rarely allowed to do creative research without interference. The National Research Council eventually placed most of its projects under military control, and depended almost entirely on the military to decide what was needed. Dupree has identified two very positive effects of wartime research efforts, however. First, industrial research became an important element in the American economy. Second, scientists gained experience in cooperative research efforts to solve particular problems; the war demonstrated the potential of having specialists work together as a team.[1114]

One important institutional change at the Armory reflected wartime concerns with production controls, but also had a lasting effect on research capability. During the first year of American involvement in the war, the Armory set up a metallurgical and chemical laboratory with its own staff of technical specialists. A new laboratory building in Federal Square included facilities for metallographic examination, chemical testing, physical testing equipment, and experimental heat treating rooms.[1115] The principal purpose of this laboratory facility, and its expanded staff, was to test the quality of steels arriving at the Armory for components, gages, and tools. By 1920, the laboratory had chemical equipment for steel and oil analyses, a Charpy impact testing machine, a metallurgical microscope, an instrument for critical point determinations, a potentiometer for standardizing pyrometers, gas fuel and electric resistance furnaces for experimental heat treating, and what was probably the old Riehle machine for testing metals tensile strength, compression, and ductility.[1116] The Armory's annual report for 1917-18 said that

> Physical and working tests are also made under the supervision of the laboratory and systematic records are kept of the quality as regards analyses, physical properties, effect on life of tools, machinability, etc, of steels from various sources of supply.[1117]

Thus the steel quality control testing and most of the experimental work on heat treating that had been done at the Water Shops moved up to the Hill and became more sophisticated.

[1114] Dupree, pp. 306-309, 314-315, 323-24.

[1115] Green, "The Ordnance Laboratory at Springfield Armory," p. 1; Arco, 1918, pp. 1059-60.

[1116] ARCO 1920, p. 14.

[1117] ARSA 1918, pp. 3-4, SANHS.

The emphasis on tool steels reflects the changes that were affecting machining processes in the early 20th century. Tool steels had been developed which could withstand higher cutting speeds, deeper cuts, and increased operating temperatures. The Armory began a much more systematic program of data collection on tool steels in 1918, looking at various heat treatments and alloy compositions. Some of the technical staff of the metallurgical and chemical laboratory were surely overseeing this program and doing some of the research in the new heat treating rooms of the laboratory building. Of course, the production shops remained closely involved and continued to serve as important testing facilities. The annual report for 1919 noted that

> most of the research work done at this Armory has been coincidental to production and this developed a practical point of view in handling all research problems.[1118]

The metallurgical and chemical laboratory, sometimes called the Metallurgical Division, was intended primarily to assist the production departments of the Armory, and continued the division in Armory research between materials testing and work on small arms. However, the laboratory also became a vital contributor to the designers in the Experimental Department who were developing new weapons. The laboratory was a source of critical expertise on many technical problems facing weapons designers, and it provided steady assistance even after it had been officially transferred to the Manufacturing Department in 1941.[1119]

The Experimental Department also got a new facility and, evidently for the first time, permanent civilian staff as a result of World War I. A small arms proving ground, with indoor ranges in temporary buildings along Pearl Street, gave the Department more capability for proof testing and ballistic analysis. There were significant additions of new equipment. The Commanding Officer justified this program by noting in 1918 that "the space and facilities for conducting experimental work at this Armory are in no way adequate for the amount of work which this department is called upon to do." Ballistic tests had a long history at the Armory, but the war created exceptional needs for data on the performance of weapons and ammunition. The Experimental Department, for

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[1118] ARSA, 1918, pp.3-4, 1919, p. 10, SANHS. Hugh Aitken, Scientific Management in Action, pp. 30-32, describes a "revolution in machine-shop practice" that came after F. W. Taylor and others demonstrated the capabilities of high-speed steels.

[1119] Green, "The Ordnance Laboratory at Springfield Armory," pp. 1-2.

instance, compiled tables of fire for use with Browning and Vickers machine guns. "As soon as values are arrived through theoretical computation they are verified by actual firing." There were also field tests of weapons at various firing ranges located outside the Armory.[1120]

Post-war Ordnance Department re-organization gave more control over research projects to an Ordnance Committee which included line officers, as we discussed in chapter 2. The Army was extremely fortunate to have a civilian researcher in this period who could work well in a more complicated administrative environment. John Garand came to the Armory in 1919 from the National Bureau of Standards, where he had worked on an experimental design for a machine gun. Like so many earlier gun makers, he had learned machining skills in the New England textile industry, and had experience in the production of machine tools. At the armory, he joined the Experimental Department and began seventeen years of effort that led to the acceptance of a new rifle. Edward Ezell has pointed out that

> Garand carried out his design work under the watchful eyes of the Ordnance Committee and numerous boards established by the Army to test self-loading rifles. Every step of the way Garand had to live with the specifications of the line officers. Their suggestions, their complaints, and their preconceptions constantly plagued him.[1121]

The base of Garand's operation was the Model Shop, built at the north end of the Administration Building in 1920 for developing experimental arms, with electrical motors driving machinery arranged in small groups for greater flexibility.[1122] It would later become a source of models for production tooling as well. The Model Shop developed as a somewhat independent section of the Experimental Department, without the larger department's responsibility for proof testing and assessment of new small arms designs, and was the first facility ever built at the Armory for the express purpose of designing new weapons. Although hardly a paradigm of concerted research team effort, the shop did represent a limited response to pre-war problems of part-time research.

[1120] ARSA 1918, pp. 10-11, 1919, pp. 10-12, 1920, pp. 16-17, all SANHS.

[1121] Ezell, Great Rifle, pp. 20-24; also see his "Search," pp. 47-52; Sharpe, 514-515; Major General Julian S. Hatcher, The Book of the Garand, pp. 28-31, 34.

[1122] ARSA 1920, p. 6, SANHS. Sharpe, p. 514A, shows a photo of Garand "in his experimental shop toolroom at Springfield Armory."

Garand was not the only designer working on semi-automatic rifles at Springfield Armory in the 1920s. John Pedersen and Capt. James L. Hatcher, head of the Experimental Department, were also developing rifles. Hatcher re-designed the gas-operated Bang rifle, invented by a Dane, but testing led to its rejection in 1922. Pedersen, paid $10,000 per year under a lucrative contract, worked from 1924 to 1931 on several versions of a rifle with a blow-back action. His final design, like Hatcher's, failed to satisfy Army testers.[1123]

Garand at first chose primer actuation as the means of operating his semiautomatic rifle. This operating system required a special form of primer which would move a short distance to the rear as the weapon fired. After modifications of early models, Garand in 1926 produced an effective rifle based on this system. Unfortunately, ammunition for his rifle became a major issue. Frankford Arsenal had switched to a progressive burning powder that would not drive the primer back with sufficient force to operate Garand's rifle. In addition, the ammunition makers at Frankford had adopted crimped-in primers to prevent the very primer movement that Garand was depending on. Another serious blow was the fact that his new rifle would not function with the ammunition left over from World War I, a vast and deteriorating supply that the Army wanted to use up. Finally, there were questions about the costs of designing and manufacturing a special cartridge for this primer-actuated rifle. Instead of accepting his rifle, the Ordnance Department asked him to design a new one with a gas-actuated operating system of the cylinder and piston type.[1124]

Strangely enough, one of the next steps in the development process was a switch in preferred caliber, in effect a major change in ammunition requirements. By the end of 1927, Pedersen convinced the Ordnance Committee that .276 caliber was best for a semi-automatic service rifle. Garand had to design his rifle for that new caliber, despite objections from the infantry that the projectile was too light and the change in ammunition too expensive. The infantry also felt that machine guns would continue to need a heavier round, thus requiring supplies of two principal cartridges on the battlefield. Although Garand's .276 caliber, semi-automatic rifle won over Pedersen's in tests, it was never accepted by the War Department. Gen. Douglas MacArthur, the

[1123] Sharpe, pp. 514-518; Ezell, Great Rifle, pp. 25-27.

[1124] Sharpe, pp. 515-516, 519; Ezell, Great Rifle, pp. 24-25, 300; Hatcher, pp. 53-54, 74-75.

Chief of Staff, stopped the proposed adoption of the .276 cartridge in 1932 because of cost and other complicating factors.[1125]

With attention redirected at a semi-automatic rifle using the standard .30” caliber cartridge in use since 1906, Garand simply turned to an existing .30” caliber version of his .276 rifle, a version he had developed on his own. This Garand rifle, which weighed only slightly more than the .276 rifle, went through additional changes as the Armory prepared a limited number for extensive testing in 1934 and 1935. In 1936 the Army adopted Garand's semi-automatic weapon as the United States Rifle, Caliber .30” M1. Garand then had to get involved in the design of tooling to convince production engineers at Springfield Armory that they could mass produce the complicated breech mechanism of his rifle. The Armory turned out the first official M1 in 1937. It did not achieve full production status for the rifle until 1939. The gas cylinder required a complete redesign by 1940, and the Armory continued to improve the weapon and its methods of manufacture during World War II.[1126]

It is no longer fashionable to stress the historical importance of individuals, but no one questions the tremendous value of John Garand and his rifle in World War II. That Garand, working with very little help in the Model Shop of the Experimental Department, was able to develop his rifle during two decades of reduced activity at the Armory is more a measure of his individual genius and tool-making skills than a reflection of the merits of the peacetime ordnance establishment. Like Thomas Blanchard, he affected the Armory as something of a ‘deus ex machina’. The United States for once had the best infantry rifle in the world, and it was designed by a government employee at Springfield Armory. No other nation had a semi-automatic rifle as its standard service arm during World War II. The rifle earned a superb reputation for reliability and shooting performance in combat. Gen. George S. Patton spoke for most World War II veterans when he said "In my opinion, the M1 rifle is the greatest battle implement ever devised."[1127]

[1125] Ezell, Great Rifle, pp. 29-33.

[1126] Sharpe, pp. 520-527; Ezell, Great Rifle, pp. 33-35, "Search," pp. 6-7; Johnson and Haven, p. 291.

[1127] Ezell, "Search," pp. 61, 175; quotation from a letter by Patton, dated 26 January, 1945, in the exhibit of the National Park Service at Springfield Armory.

Constance Green, careful historian and Armory employee during World War II, said that in the 1920s Model Shop work "constituted so essential a part of Armory activities that it might be called the 'raison d' etre' of the Government plant."[1128] The success of the M1 development was a high note in a sad song of institutional decay between the world wars. As we noted in Chapter 2, the end of "the war to end all wars" led to a great decline in public concern for the readiness of the U. S. Army, and to a corresponding lack of interest in maintaining the Armory system at a high level of productive capacity. The military was flooded with weapons for a huge wartime force, but the size of the regular army had dropped dramatically by the 1920s. Staff reductions, which eventually reduced the Armory production force to a perilous dependence on a few senior employees, also hit hard in the small Experimental Department and the separate Metallurgical Department. It was these departments, however, which provided the basis not only for the new rifle, but for Army small arms research and development during World War II.

The Experimental Department had to make do with far fewer employees after 1920. The wartime and immediate postwar strength of the department had risen to forty-six civilians and two officers. Staff reductions began in 1920, leaving only 20 civilians under a single officer. Despite the movement of the Aircraft Armament Division to Springfield in 1922 and the assignment of its two officers and five civilians to the Experimental Department, only sixteen civilians were left in 1923 when another cut reduced their numbers to four at one point. The four were listed as a foreman, a test engineer, a photographer who also did small arms targeting, and a clerk. The Metallurgical Department was temporarily down to nine employees in 1924. As the Great Depression led to even leaner times at the Armory, the skeletal research departments temporarily merged. In 1930, the Armory commanding officer named one officer the Director of Research, without any department of his own, to somehow keep track of all research and development done in various departments, shops, laboratories, proving ranges, etc. By the mid-1930s, the two departments became parts of a Research Department which probably functioned in name only, as a collection of separate facilities. This loose structure encompassed the research and development sections through the increased activity and equipment accompanying the preparations for M1 production.[1129]

[1128] Green, "The Ordnance Laboratory at Springfield Armory," p. 1.

[1129] Green, "The Ordnance Laboratory at Springfield Armory," p. 1; ARSA 1922, p. 18, 1923, p. 23, 1930, p. 7, all SANHS.

The increased importance of research for wartime planning in the late 1930s did not vitiate the Ordnance Department's focus on anticipated production demands, however, which probably explains the lack of real coherence in the Armory's research structure. The Chief of Ordnance rejected suggestions made in 1940 to create a Research and Development Division, and in July 1941 the departmental Technical Staff--which had coordinated and suggested research projects since 1919--was abolished and absorbed into the manufacturing arm, then called the Industrial Service.[1130] About this time, the Armory's Research Department became the Engineering Department. Although this reorganized department had a section devoted to materials research, the metallurgical laboratory was now placed under the much larger, and quite separate, Manufacturing Department, reflecting the laboratory's origins as an adjunct to production. The Engineering Department's general activities concerned procurement of small arms materiel for "fabrication by the Armory and purchase from commercial concerns," but an Experimental Division continued development work on new small arms including machine guns, anti-tank weapons, a modified Browning Automatic Rifle, and a pilot model of a new light rifle.[1131] The relatively narrow focus of research efforts was soon to balloon under vastly increased wartime pressures.

Wartime Challenges and Postwar Omens, c1941-1945

By the summer of 1942, wartime reorganization of the Ordnance Department established new priorities at high levels of command, requiring continual Armory action in concert with private contractors and with other military facilities. The department retained control of virtually all small arms projects throughout war, choosing not to involve the Office of Scientific Research and Development's network of academic specialists, and finally attempted to rationalize all department research within a Technical Division. This division, renamed the Research and Development Service in 1944, included a Small Arms Development Branch which took over most experimentation until late 1943, while the Armory's staff concentrated on the pressing demands of wartime production.

The Small Arms Development Branch continued to supervise some research at Springfield,

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[1130] Green et al., pp. 85, 88.

[1131] ARSA 1941, pp. 18-20, SANHS.

especially the evolution of the lightweight rifle discussed in the following pages, but the Armory renewed its direct involvement in development work, mainly in the Engineering Department's Experimental Division.[1132] Extraordinary production and product improvement demands in early 1942 led to expansion of the Experimental Division, with creation of design and patent sections, and with the absorption of the Model Shop under John Garand.[1133]

Study of monthly research and development progress reports, from late 1942 through 1945, shows the Armory pursuing many different lines of research and development under emergency pressures of the largest war in which the United States had ever been engaged. These classified reports went to various departments and government agencies, some of which had actually initiated specific projects and had a direct interest in their progress, and notified agencies and individuals of the availability of additional information, usually in the form of technical reports.[1134] We have not attempted to unravel the full network of research and development demands made on the Armory in this period, but even within the Ordnance Department's small arms purview these demands were very numerous. The strains of this complex and demanding research environment are readily apparent in the wartime reports.

Constance Green, who paid a great deal of attention to research in her summaries of Armory activities, says that there was little expansion of staff in the Experimental Division after 1942. She credits approximately sixty-four people for most of the work of the division, which she describes in general terms as "design and fabrication of new weapons and accessories, test of design modifications, test of material changes, consultant work for manufacturing facilities, and engineering inspection." The work by Garand and his staff on modifications to the M1, and on production engineering that improved its manufacture, received special praise from this knowledgeable observer and institutional historian.[1135]

[1132] James P. Baxter, Scientists Against Time, p. 31; Green et al., pp. 96, 117; Ezell, Great Rifle, pp. 42-51.

[1133] ARSA 1942, p. 23, SANHS; Green, "The Ordnance Laboratory," pp. 1-2.

[1134] Lt. Col. Whittaker to Chief of Ordnance, 15 May, 1945. Included in file no. 319.1, "Springfield Armory Monthly Report of Progress on Research and Development Projects, May 20, 1942 - December 20, 1945." Hereafter cited as SA-R&D. We are grateful to Edward Ezell for loaning us his copy of this document.

[1135] Green, "The Ordnance Laboratory" p. 2. See also sections on research throughout Volume II, Book III, of her "History of Springfield Armory."

Although the range of research projects was extensive, there were only a few which received attention in the progress reports month after month. Continuing projects ranged from the practical, such as finding a way to reduce friction in the breech mechanism of the M1 rifle, to more esoteric problems like studying the use of boron-treated steels. Sometimes long-term projects were temporarily halted because of higher Armory priorities, or were linked to other research efforts and forced to wait for results.

A project to investigate the effectiveness of the gas cut-off and expansion principle for the M1 was both the victim and the cause of such delays. As we discuss later in this chapter, this principle was to become an important element in the development of the M14 rifle. By the spring of 1943, Armory researchers had made sketches of a modified M1 gas system based on the 1933 White patent noted in the following pages. Despite satisfactory results in early testing of system components, work on the project halted in August, 1943. This suspension of "fabrication of parts" needed to modify an M1 was "because of priority of other work in the shop." After researchers resumed work and continued the usual cycles of testing and redesign, experimentation with gas cut-off and expansion was linked to the ongoing development of "an Improved Design of Caliber .30" S.A. [semi-automatic] Rifle." Design of the new rifle was put on hold until the potential of the gas cut-off system on the M1 was fully evaluated. Yet a month later, in July 1943, the Armory reported that "Little progress has been made on fabrication of models applying the gas cut-off and expansion principle to the M1 rifle because of comparatively low priority of this work." The war ended with results from later tests uneven, but with the impressive potential of gas cut-off clearly demonstrated. All work on either the cut-off system or the improved semi-automatic rifle had been considered "inactive" at the Armory, awaiting further instructions from the Chief of Ordnance, since March 1945.[1136]

[1136] See SA-R&D, 20 April, 1943, p. 1, 20 July, 1943, p. 1, 20 Aug., 1943, p. 1., 20 June, 1944, p. 10, 20 July, 1944, p. 12, 20 Sept., 1944, p. 9 (first test of M1 with gas cut-off), 20 Dec., 1944, p. 8, 20 March, 1945, p. 8; and R. Blake Stevens, <u>U.S. Rifle M14 From John Garand to the M21</u>, P. 92. The improved semi-automatic rifle was called the M2 from June, 1943 to March, 1944. It should not be confused with the T20 rifle, which was being developed at the armory at the same time. The latter was a selective fire version of the M1 rifle with a 20 round magazine, but it did not include the new gas cut-off and expansion system. 100 T20E2 rifles were being produced at Springfield at the end of the war, and the Ordnance Technical Committee had recommended procurement of 100,000. Ezell, <u>Great Rifle</u>, pp. 51-56, refers to the T20E2 as the M2 rifle.

Problems appearing in standard weapons after issue to the troops caused considerable concern at the Armory, and usually received higher priority than did the development of new weapons. The persistent difficulty with friction in the breech mechanism of the M1 caused research on various lubricants, on hardening processes, and on the addition of a roller to the rifle's bolt. Wet weather and dust aggravated the problem and were important factors in testing programs.[1137]

Testing at the Armory occasionally had an informal “Rube Goldberg” flavor, as creative researchers came up with ways to assess the value of various products and procedures. Efforts to develop an M1 clip that would "improve holding of first and eighth cartridges" would have impressed the famous cartoonist of outlandish technology:

> Since last report the test of these clips loaded and placed in bandoleers and hung from a roof bow of an army truck used daily between Hill and Water Shops has been completed. After four days it was found that many of the rounds were completely dislodged from the clips. This condition was prevalent in all four types of clips and no general trend was indicated. This test being too severe, two different shaking tests proved to be too mild. Finally, by dropping loaded bandoleers repeatedly from a height of 30 inches a definite comparison of the effectiveness of clips to retain cartridges was obtained, indicating that the present clip was best...[1138]

Much of the testing done at the Armory was endurance testing under simulated field conditions. Reports from combat commands directly influenced testing programs at Springfield, an example of feedback in the military system. The feedback loop was completed when the Armory, after research and testing in search of a solution to a reported problem, sent back an improved weapon, component, or maintenance procedure for evaluation in the field. The ultimate test was combat.

When Armory researchers found a way to improve the durability of the extractor in the M1, through shot-peening with "only minor revision of production fixtures," they asked in January 1945 for approval from the Office of the Chief of Ordnance to require the change. The Experimental Division had in this case, as in others, designed and built its own testing machine for endurance testing of this

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[1137] See, for example, SA-R&D, 20 Nov., 1942, p. 6, 20 July, 1943, pp. 13-15.

[1138] SA-R&D, 20 May, 1942, p. 25.

part. Testing and report writing continued on the new process for extractors, pending approval. In April 1945, the Armory received authority "to process 100,000 extractors to permit accumulation of service experience." A detailed report on experience with 75,000 of the shot-peened extractors was being prepared when the Japanese surrendered.[1139]

Armory researchers tried to anticipate problems that might arise if sources of essential ordnance materials were lost or shortages occurred during the course of the war. They spent a great deal of time seeking alternatives to black walnut as the standard material for gunstocks. When the war made it increasingly difficult to get China Wood oil, synthetic and natural oils of various types were tried on gunstocks. They even worried about metal shortages that could hinder the production of links for machine gun ammunition belts. The answer was a fabric ammunition belt.[1140]

Working with other institutions in cooperative research efforts became much more common during the war. One case which became very important in later rifle and machine gun development was the research on the chrome plating of barrel bores. Springfield Armory, with input from the Bureau of Standards and the Battelle Memorial Institute, developed ways to plate bores to improve their erosion resistance.[1141]

Sometimes an experimental technology looked very promising but was difficult to apply in the mass production of a particular part. Armory researchers spent years trying to improve the working life of M1 firing pins, components which were subject to sudden, repetitive shocks in semi-automatic fire. They examined the condition of machined surfaces; tried various metal alloys, forging processes, and heat and chemical treatments; and experimented with shot-peening. As in the case of the extractors mentioned above, the peened firing pins, with deformation-hardened and strengthened exteriors, held up very well in endurance tests. Firing tiny shot at the firing pins so that they would ultimately be able to fire more M1 cartridges seemed to be the best, if ironic, answer. In setting up

[1139] SA-R&D, monthly reports from 20 October, 1944 through 20 August, 1945. See also Green's comments on the design of special testing machines in "The Ordnance Laboratory," p. 10.

[1140] SA R&D, See, among others, monthly reports of May 20, 1942, pp. 23, 30, 34, Dec. 20, 1942, p.8, April 20, 1943 p. 11, August 20, 1943, pp. 7, 11; Green, "The Ordnance Laboratory at Springfield Armory," pp. 6, 12-13.

[1141] Green, "The Ordnance Laboratory," p. 11.

production fixtures in 1945, however, designers had trouble getting a full 360-degree rotation of the pin during peening. They were still trying to get the right fixture built when the end of the war halted their efforts.[1142]

"Compression rifling," another new technology which seemed to have great potential, proved even more frustrating. In this case, both private contractors and another Ordnance Department facility became heavily involved in the research effort. By April, 1945, Springfield employees had successfully pulled a tool through a six-inch barrel to form two rifling grooves. They wanted to try a four-groove tool and a full length rifle barrel, but higher priority tasks at the Armory interfered. As part of the "Investigation of Compression Rifling," the Armory gave a "development order" to the P. & F. Corbin Company of New Britain, Connecticut, to investigate this process. Corbin had a great deal of difficulty with the .30” caliber, four-groove barrels using a broaching machine to pull the tool. Remington Arms had better luck with two groove rifling, using a swaging process that pushed the tool, but four-groove, swaged rifling was much harder to accomplish. A conference with representatives of the Inland Division of General Motors, who were working on a similar investigation, produced nothing new. Problems continued in 1944, and the research effort shifted to Watertown Arsenal, which had the capability to test direct application of high pressure hydraulic equipment to the rifling process. Watertown technicians tried pulling a floating "button" through .30” and .50” caliber barrels, with only partial success. This form of swaging was still under investigation, without solid conclusions, as the nation entered peacetime.[1143]

The Armory's World War II research, although impressive in comparison with the minimal achievements of similar work during World War I, produced few dramatic results and looks insignificant beside the enormous research programs of the Office of Scientific Research and Development. The well-coordinated, heavily-academic, and remarkably productive research of the OSRD was a critical factor in victory. Besides the obviously important atomic bomb, OSRD products and scientific findings were essential to the war effort in hundreds of ways. Teams of civilian specialists focused on problems, saw needs, opportunities, and solutions that the military

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[1142] See, for example, SA-R&D, 20 May, 1942, p. 1, 20 Dec. 1942, p. 9, 20 May, 1943, p. 16, 20 Nov., 1944, p. 3, 20 Feb., 1945, p. 2, 20 Aug., 1945, p. 2.

[1143] SA-R&D, 20 April, 1943, pp. 2-3, and continuing monthly reports through December, 1945.

often did not recognize, and got results in a hurry. Establishing priorities for projects of clear importance, but allowing creative scientists to innovate and generate new ideas as they worked, the OSRD effectively tapped the potential of science to affect the direction of modern warfare. As James Phinney Baxter concluded in his official history of the OSRD, "It was our good fortune, in World War II, to have a better organization of science for war than our friends or foes had."[1144]

The need for ongoing military research was clearer than ever as the war ended. A new type of research had also shown its potential and would have important implications for small arms development. Operations research in the OSRD had brought rational, and usually numerical, analysis to the study of operational problems, by carefully measuring both job requirements and human characteristics in work with complex mechanisms. Baxter believes that "The extension of scientific aid into the realm of operations is an innovation of World War II." Gut reactions and prevailing military prejudices had always played a major role in the determination of operational needs and the evaluation of effectiveness. Eventually, the type of analysis begun by operations researchers in the OSRD and in the Air Force was used in cost-effectiveness studies and came to dominate decision-making at the highest levels of the military establishment. Cost-effectiveness determinations were used, probably incorrectly, in deciding the fate of Springfield Armory.[1145]

The Armory had always placed production above research and development. As production requirements contracted at the end of the war, it was clear that Springfield's traditional status was in question. Although the success of Armory M1 manufacture had been extraordinary, private industry had also made great contributions to the war effort, demonstrating to many observers its capability to take over most, or even all, of the manufacturing role of the federal arsenals. For the first time in nearly seventy years, this possibility was raised and, at last, made a serious factor in future military planning. The arsenal system had, after all, never been able to supply all the small arms needed in any major war. The public believed that the greatest achievement of the Springfield Armory in the twentieth century was the development of the M1 rifle. The Armory had a good opportunity to perpetuate a major role for itself in research and development, in part by playing down the fact that the M1 was the result of a poorly-supported research effort based on the exceptional talents of one

[1144] Baxter, p.449.

[1145] Baxter, pp. 403-4; Ezell, "The Death of the Arsenal System," SANHS, pp. 3-6, 31-33.

individual. Building up the Armory's capability in research and in production engineering was a shift in focus for an institution that had always prided itself on manufacturing, but it was clearly necessary if Springfield were to have a secure place in the military establishment of the postwar period.

The M14 Rifle and the Fate of Armory Research and Development, c1945-1968

After the defeat of Germany, production at Springfield fell sharply, but research and development efforts actually increased in a newly focused framework. In April 1946, a Research and Development Service was set up at the Armory (this was to become the Research and Development Department in 1947). Development projects were given to individual project engineers for supervision from start to finish. Some important new facilities were added as necessary, including a Casting Laboratory established in 1947 to study precision casting and its applications for small arms manufacture (castings could cut machining time and costs). In the same year, a single office took over the administrative work that had been done by the many separate groups working on development; and special sections for particular weapon types were set up, including one for development of rifles. Organizational changes continued into the period of the Korean War, but the Armory-wide reorganization of 1950 put the Research and Development Division (formerly the department, and before that the service) in a strong position. By 1951, Research and Development was one of four main Armory divisions, with broad responsibilities within the Ordnance Department and control over all testing as well as design facilities. An industrial laboratory in this division, heir to the earlier metallurgical and chemical facility so tied to production, now made all such tests for both research and manufacturing purposes. The organizational placement of the laboratory probably reflected the contraction of primary manufacturing responsibilities to development of pilot lines for use by private contractors. Pilot line production, although conducted through the Armory Industrial Division, was closely linked to Research and Development responsibilities for technical assistance to contractors and development of engineering tests. The Armory was in the uneasy position of fostering the private capabilities which threatened to eliminate the need for Armory services.[1146]

The Armory's research role become even more important as the emphasis on production diminished further after the Korean War, and the loss of the Armory mission for national procurement of small

[1146] SAHS, 2 Sept. 1945 - 30 June, 1951, pp. 104-107, 1 July 1951 - 31 Dec. 1951, p. 1, 40.

arms after the 1955 establishment of the Ordnance Weapons Command, as outlined in chapter 2.[1147] Development of aircraft armaments, heavy and light machine guns, a recoilless rifle, and the lightweight rifle kept a large staff busy in the 1950s. Research on new production technology continued to improve manufacturing capability and was used extensively to assist contractors. A precision casting section was one of the subdivisions looking into advanced methods of parts production; by 1958, the success of this section warranted its formal incorporation into Armory production operations as M14 pilot production began. By 1956, work had begun on ultrasonic testing of cast and sintered parts. Later the Armory would experiment with investment casting of selector switches for the M14 rifle.[1148]

Springfield was still doing well with most of its technical research in the early 1960s, and its work in the development of the M79 grenade launcher, the M60 machine gun, and multi-barreled aircraft armaments would prove to be significant small arms advances. It had proven that it could work with private industry on joint development projects, and in some cases contributed to important work on processes with general industrial applicability such as ultra high-speed machining of wood with carbide tools, use of refractory or exotic metals, use of numerical controlled machine tools in small lot and pilot line production, and analog computer testing of design modifications without actual manufacture of components.[1149] Yet difficulties in the prolonged, all-important program to develop a new service rifle put these successes in the shade. The Armory had badly needed another triumph in rifle design to follow up on Garand's great achievement. To the dismay of everyone at Springfield, the M14 rifle, which was eventually adopted by the military, turned out to be a disaster for the Armory's reputation as a center of small arms development. We present this story, well-told in works by Edward Ezell and Blake Stevens, in some detail here because of its importance in the eventual closing of the Armory.

The M14 rifle has been called a "product-improved offspring" of the M1 Garand rifle.[1150] Indeed,

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[1147] SAHS 1 January 1955 - 30 June 1955, p. 1.

[1148] SAHS 1 January 1956 - 30 June 1956, pp. 4-5, 1 January 1958 - 30 June 1958, p. 3.

[1149] Thomas A. Moor and William P. Goss, The Springfield Armory, A National Historic Mechanical Engineering Landmark; Walter I. Howe and Col. E.H. Harrison, "The Modern Springfield Armory," p.22.

[1150] Ezell, Great Rifle, pp. 138, 145. Ezell provides detailed and perceptive coverage of the development process and the controversy surrounding the adoption of the M14. See also R. Blake Stevens, U.S. Rifle M14 From John Garand to the

the design of the M14 owes much to the first semi-automatic service rifle, and some parts are interchangeable between the weapons. The development of the M14 began with efforts to improve or increase the capability of the M1, and was complicated by the search for a lightweight successor to the M1.

The M1 underwent considerable modification as it was rushed into production and even during its use in World War II, "the ultimate weapons trial."[1151] Some problems and deficiencies identified in combat, or in tests conducted during the war by the Ordnance Department, led to experimental projects and to the development of prototype components that were not immediately adopted. Combat of many types, in widely varying conditions, also identified needs that the M1, as designed, could not satisfy operational needs that prompted wishful thinking in both the combat service branches and the Ordnance Department.[1152]

The M1 was a remarkably tough rifle that would continue to function under all but the most terrible field conditions. It stood up to incredible abuse, but ordnance officers soon noticed one significant weakness: in heavy rain, the lubricant on the bolt lug and in the canning groove of the operating rod could be washed away, causing the action to "freeze." Efforts to solve this problem led to experimental rifles with a different cam angle cut in the operating rod, and to the addition of a roller on the canning lug. The M1E3, developed at Springfield Armory in 1943 with Garand's active participation, had both of these modifications. By the time testing of the M1E3 was completed, in mid-1944, production of the M1 was so well-organized and effective that the Army decided to put off adopting the new features which had proven successful on the experimental M1E3. Instead, riflemen were issued small containers of a water-resistant grease, which fit into the stock of the M1 behind the butt plate. The Armory's experimental division tried various ways to improve the M1 during the war, producing a series of "E" models, all of which were semiautomatic and used the 8-round clip of the standard M1.[1153]

M21.

[1151] Stevens, p. 8. For details of redesign, modifications, and continuing research on M1 improvements, see Green, "History of Springfield Armory," Vol. III, pp. 247-254.

[1152] Stevens, pp.; Ezell, Great Rifle, pp. 41-43; Hatcher, Book of the Garand, pp. 240-254; Sharpe, pp. 520-525.

[1153] Stevens, pp. 12-15; Ezell, "Search," pp. 402; Green, "History," Vol. II, pp. 247-248, 378, 691; U.S., Ordnance Department, Small Arms and Small Arms Ammunition, pp. 18-23; "Post W.W. 2 Rifle Development," Springfield

Troops in combat soon learned to appreciate the semi-automatic operation of their service rifle, but many envied the full-automatic capability of the Browning Automatic Rifle (BAR), and the Thompson sub-machine gun, both of which had detachable magazines with large-capacities. A few enterprising soldiers tried unauthorized modifications of M1 rifles to create crude but workable fully automatic weapons. At Springfield Armory, Garand began working, with much greater care and technical sophistication, on a selective-fire version of his M1. Responding to a request from the Ordnance Department, he tried to fit a twenty-round BAR magazine to an experimental M1 that could fire with either semi- or full-automatic operation. Unfortunately, the standard BAR magazine would not work properly with the M1 receiver.[1154]

After the bulk of small arms experimental research shifted back to the Armory in late 1943, Col. Rene Studler's Small Arms Development Branch at the Pentagon continued to supervise the effort to develop a selective-fire rifle. Studler's office made this effort a formal project of Springfield Armory in May 1944. Later in that year, the Ordnance Technical Committee recommended a nine-pound, selective-fire weapon that would use a twenty-round magazine and have both a bipod and a folding stock. To top off this wish list, the committee wanted this new rifle to be based on the nine and a half pound, .30” caliber M1, with only limited tooling changes to be required. The Ordnance Department awarded a contract for the development of this new rifle, the T22, to Remington. At the same time, the existing Springfield Armory project went forward with what had become the T20 rifle. Colonel Studler supervised both of these projects from Washington.[1155]

In 1941, Studler had suggested that Springfield Armory hire and train Earl Harvey as a small arms designer. Harvey proved to be a gifted engineer and ended up working in the Experimental Department on a new type of gas system for operating a rifle. One of the persistent problems with the M1 was the violent action of its impinging gas system. The long and relatively delicate operating

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Armory National Historic Site Fact Sheet #4.

[1154] Record of Army Ordnance, Vol. 2, Book 1, p. 26.

[1155] Ezell, Great Rifle, pp. 42-51; Green, "History," Vol. II, pp. 525-526, refers to a model for an M2 rifle in the summer of 1944, probably an early prototype of the T20. The 1945 T20E2 became the M2 (Ezell, Great Rifle, pp.51-57), but it never went into production. Numerical designations are very confusing in this period.

rod and gas piston was subjected to high stress as a result of the shock of high pressure gas suddenly hitting the face of the piston. Studler asked Harvey to investigate other gas systems in 1943, and the young designer turned to the 1933 patent of Joseph C. White, which covered a gas cutoff and expansion concept. The idea of a cutoff device and "expansive working" went back to the steam engines of the mid-nineteenth century. George Corliss became famous for the rapid cutoff action in his engine, which utilized the expansive power of steam in the cylinder and produced great fuel savings.[1156]

A gas system with a cutoff admitted high pressure gas from the barrel for only a brief instant, and then allowed that gas to expand as it worked against the piston. The smooth and progressive action of the expanding gas moved the operating rod with less shock than an impinging gas system, but tests of experimental rifles using various forms of gas cutoff from 1943 to 1944 did not warrant an immediate change in the M1. Garand still preferred his own impinging gas system and retained it in the 1944 design of the T20. Harvey's work on gas cutoff and expansion was, however, not forgotten.[1157]

Garand's T20 used the same type of roller he had developed for the bolt of the M1E3. The first model of this rifle to be tested, as might be expected, had a number of weaknesses. One was a receiver longer than that on the M1. In order to use the BAR magazine, Garand felt that he had to lengthen the receiver, a change which would have complicated the switch from production of the M1. Other problems included an open bolt design for full automatic fire, a new gas cylinder lock, and a recoil check that did not allow for a bayonet attachment, a flash hider, or a grenade launcher. During the development process, the Army gave up the idea of a folding stock. The next model, the T20E1, got a special 20-round magazine of its own, but for better feeding and extraction, the receiver was kept slightly longer than the M1 receiver. The T20E1 could fire selectively with a closed bolt, could accept a bayonet, and had a bipod. Testing in 1945 led to a further improved version, the 9.6-pound T20E2. Its magazine would work in a BAR, but not vice versa; and it could accept a grenade launcher or a flash hider. With its bipod and an empty magazine, it weighed in at a

[1156] Stevens, pp. 16-17; Ezell, Great Rifle, pp. 67; Green, "History," Vol. II, p. 525; Louis Hunter, Steampower, pp. 142-144, 256-259.

[1157] Stevens, pp. 12, 16-22; Green," History," Vol. II, pp. 378-379, 525-526; Record of Army Ordnance, Vol. 2, Book 1, pp. 20-21.

substantial 12.5 pounds, but it could fire standard .30” caliber rifle cartridges at a cyclic rate of 700 per minute.[1158]

The end of the war alleviated the urgent need for a selective fire rifle that could be put into production rapidly. Remington's experimental models, which stuck closely to the design of the M1 receiver, were tested and shelved. Armory engineers estimated that they could have made the T20E2 using as much as 85% of the tooling already developed for the M1. Although the Ordnance Technical Committee had recommended the manufacture of 100,000 T20E2 rifles soon after the defeat of Germany, no production efforts had begun on what would have been the M2 before the Japanese surrendered. The Ordnance Department now had time to think carefully about the operational needs of the post-war military, about the combat requirements of the future. The first thing to consider was a change in ammunition that might make the long-desired lightweight infantry rifle a reality.[1159]

It was very difficult to design a rifle weighing less than ten pounds which could handle the recoil and the heat produced by firing the standard .30” caliber cartridge in full automatic mode. Most soldiers simply could not control a rifle firing that type of cartridge at a high cyclic rate. The Germans, recognizing this problem during the war, had tried a shorter and less powerful 7.92 mm cartridge, the Kurz (short). American infantry officers generally opposed any sacrifice of ballistic performance. They liked the range and the "stopping power" of their M1 rifle ammunition.[1160]

The Ordnance Department was working on a new cartridge shorter than the existing rifle ammunition but with the same .30” caliber (7.62 mm) and similar ballistic properties. This powerful but compact round, known as the T65, offered hopes for a lighter weight rifle with no sacrifice in firepower. Colonel Studler and his Small Arms Development Branch began a major effort to design a new lightweight rifle soon after the war ended. As Edward Ezell has so clearly demonstrated, the Army set impossible requirements for this new automatic weapon: it was to weigh only seven pounds, to use a full power cartridge, and to replace most of the small arms in use by the

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[1158] Stevens, pp. 27-30, 77-79. Stevens' volume contains a reprint of TB 9X115, the Army's instruction manual for the T20E2. See also Ezell, Great Rifle, pp. 41-46, 51; Record of Army Ordnance, Vol. 2, Book 1, pp. 28-31.

[1159] Ezell, Great Rifle, pp.51-58; Stevens, pp. 79-88; Harkins, "Post W.W.2 Rifle Development."

[1160] Stevens, pp. 92-96; Ezell, Great Rifle, pp. 92-94; Sharpe, p. 638.

infantry.[1161]

Earle Harvey had already been working on concepts for a lightweight rifle, when Studler turned to him in 1945. He was on attached duty in Studler's office when the project got underway, but from 1946 to 1949, he did much of his development work on the T25 at the Springfield Armory. John Garand and Cyril A. Moore also produced experimental lightweight rifles at Studler's request during this period. Although none of these efforts were fully successful, Harvey came closest to getting his T25 rifle adopted. Neither he nor anyone else was going to solve the root problem of combining light weight with high powered ammunition. He found the experience of developing his new rifle at Springfield to be highly frustrating. The resistance he encountered in the production branch of the Armory convinced him that "doing R&D in an industrial, production-oriented installation was a real and substantive handicap."[1162] Garand, who had dealt with the limitations of Armory research for decades, finally retired from government service in 1953, with his M1 still the standard service rifle.

In addition to the T25, the Army tested converted M1 rifles that could fire the new .30" caliber cartridge in semi- or full-automatic modes, and several foreign rifles chambered for .280 caliber cartridges including the impressive Belgian FN FAL. In the early 1950s, no resolution of the problem of rifle selection was in sight, but there were international issues involved in the choice of a cartridge for a new rifle. Foreign policy had intervened in the already complicated search for an infantry rifle.[1163]

The effort to standardize rifle ammunition among members of NATO led to serious differences of opinion over cartridge size and power, with the Americans wanting their new T65 .30" caliber cartridge as the standard. The opposition of the British, who favored a .280 caliber cartridge, was overcome in 1954. The British gave in and adopted the T65 cartridge for their chosen rifle, the FN FAL. Apparently, they had reason to believe that in return for their acceptance of the American

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[1161] Ezell, Great Rifle, pp. 69-71. Ezell provides more detail on the extensive and unrealistic requirements the new rifle was supposed to satisfy.

[1162] Ezell, Great Rifle, pp. 69, 72-77, 81, 85.

[1163] Ezell, Great Rifle, pp. 84-88.

cartridge, the Americans would adopt the same Belgian-designed rifle. They were wrong.[1164]

Rifle trials continued after Harvey's final T25/T47 was dropped from consideration in 1953. The Ordnance Department hoped to find an acceptable rifle based on the proven M1 breech mechanism. Engineers at Springfield Armory believed that such a rifle, unlike Harvey's more radical T25, would require minimal production changes and could be issued with less delay. Ezell notes that "Emphasis on product improvement was to carry the day."[1165] Amory engineers had reexamined Garand's selective fire T20E2 and other experimental rifles based on it. By 1951, they had developed a new rifle with a cutoff gas system, a selector switch, and a 20-round magazine: the T44. This rifle was based on earlier designs by Garand and Harvey and on the recent efforts of Lloyd Corbett at the Armory. The T44 barely survived the tests of 1953, but Lt. Col. Roy Rayle, who took over the Armory's Research and Development Division that year, managed to keep the project alive. The overburdened Armory got outside help from the Mathewson Tool Co. in preparing T44 rifles for testing. The receiver, which was based on the T20E2, had to be shortened for the NATO cartridge (the Army's T65), and there were many modifications during years of rigorous trials. The T44 ended up competing against both an American (the T48, made by Harrington and Richardson) and a Belgian version of the FN FAL.[1166]

By the fall of 1955, the T44 had proven to be at least the equal of the FN FAL rifle, and it was an American design. The final trials, in 1956, showed that the T44 was probably the best choice, but the board made no decision. Despite influential voices from abroad favoring the rifle adopted by Britain and other NATO nations, the Chief of Staff chose the T44 in 1957. Ezell concludes that "in the long run, economic and nationalistic considerations held sway." The Ordnance Department clearly believed that they could use most of the M1 tooling to produce the M14, an assessment that proved to be overly optimistic.[1167]

[1164] Ezell, Great Rifle, pp. 87-107.

[1165] Ezell, Great Rifle, pp. 114-117.

[1166] Ezell, Great Rifle, pp. 114-130; Stevens, pp. 149-173; Harkins.

[1167] Ezell, Great Rifle, pp. 131-135.

Many Army officers were not happy to see the M1 abandoned; they feared the logistical and tactical consequences of equipping every soldier with a rifle capable of automatic fire. As a result of Army conservatism, the standard procedure was to issue selective-fire weapons to only two soldiers in each squad, thus simply replacing the BAR with the M14.[1168] The Marine Corps in Viet Nam used one selective-fire M14 in each four-man fire team. Without a selector switch, the M14 was limited to semi-automatic fire. Conservative officers in the 1950s and 1960s used the same arguments against selective-fire rifles that their predecessors had used against magazine rifles in the last century.

When the M14 was first adopted, there was a second model, the T44E5, intended for the role of the fully-automatic rifle. The selector-equipped M14 did not perform well in tests of fully-automatic fire. It was too light for such operation, at 9.29 pounds with an empty magazine and 10.36 pounds with a full one. Even with its flash suppressor, which acts also as a compensator or brake to reduce muzzle climb, the rifle was hard to hold on target in automatic fire. The heavy-barreled T44E5, which had a bipod to steady it in fully-automatic mode, did much better, though still not as stable as the heavy and highly-specialized BAR it was supposed to replace.[1169]

An improvement in the M14 barrel, after the weapon was adopted, led to the scrapping of plans for the T44E5, which was to have been the M15. In 1956, the Army decided to chrome plate the barrels of the M14 to increase barrel life, ease cleaning efforts, and improve the rifle's capability for sustained fire. As we noted previously, Springfield Armory had conducted research on this procedure during World War II. Marine Corps tests of the M14 in 1958 showed that the chrome-plated barrels held up well against the heat of sustained automatic fire. The Marines tried the bipod on the M14 with chromed barrel and found that it shot adequately as a fully-automatic weapon. They decided to rescind their order for the new, heavy-barreled M15 and to simply put a selector switch and bipod on those rifles they wanted for automatic riflemen. The Marines also requested a ventilated hand guard, which they considered very important in dissipating heat from the barrel. The Army quickly developed a ventilated fiberglass hand guard and a better bipod. In 1959, the Infantry Board recommended adopting these modifications for selective-fire models of the M14, and the

[1168] Ezell, Great Rifle, pp. 135-137.

[1169] Ezell, Great Rifle, pp. 136-138; Stevens, pp. 188, 200.

Army dropped the M15 before it ever went into production.[1170]

The light-barreled M14, with the addition of a selector switch and a bipod, and with a hinged butt plate to press down on the shooter's shoulder, was asked to play a role for which it had never been intended. It was never an effective fully-automatic rifle, never a proper replacement for the BAR.[1171] The M14 was, however, a very reliable and effective infantry rifle, a weapon which author Malone used in Viet Nam and for which he has great respect. A modified version of the M14, now called the M21, is still the sniper rifle of the Army, and M14 rifles dominate American high-powered rifle competitions.[1172]

The design of the M14 rifle was a public relations problem for the Armory, and the fact that private industry made most of the M14s for the military seemed to prove to some analysts that neither the Armory's manufacturing nor its research and development roles were necessary for national defense. In 1962, even the value of pilot production lines at Springfield was seriously questioned. The following year saw the merger of the Armory's Research and Development Division with its Engineering Division. The Armory, which had become world famous for rifle development and production, thus had only a limited role in the selection and procurement of the .223” (5.56 mm.) caliber M16 which replaced the .308” (7.62mm) caliber M14. Edward Ezell says that Springfield was "bypassed" in this procurement process and points to the harm which resulted. The weapon offered to the government by Colt Industries in 1963 "as a finished product ready for production" was actually far from perfect and caused severe difficulties for troops in Viet Nam. The embarrassment of the Department of Defense over well-publicized malfunctions of the rifle in combat and flaws in the M16 procurement and quality assessment programs should have caused responsible officials to reconsider the wisdom of letting a weapons command in the Midwest supervise development and manufacturing of weapons in distant factories. Unfortunately, by 1965, Springfield Armory had no future in government plans, although limited design and engineering work continued on aircraft armament. With the unsuccessful move of Armory research expertise and

[1170] Stevens, pp. 187-189, 201; Ezell, Great Rifle, pp. 138, 147.

[1171] Ezell, Great Rifle, pp. 138, 147.

[1172] Stevens, pp. 297-298, 304-308, 313. Stevens is an outspoken admirer of the M14. Richard Harkins of the Springfield Armory National Historic Site has competed with the M14 and considers it more accurate than the M1.

personnel to Rock Island Arsenal during Armory close-out phases, the Army sacrificed skills which it has never replaced.[1173]

ABBREVIATIONS IN NOTES

ARCO	U.S., Ordnance Department, Annual Report of the Chief of Ordnance to the Secretary of War for the Fiscal Year Ended June 30, ----.
ARSA	Annual Report of Operations at the Springfield Armory. Titles vary, and reports appear in different archival sources, as noted.
RG 156/	Record Group 156, Records of the Office of the Chief of Ordnance, National Archives. Record entry number follows slash.
SAHS	Springfield Armory Historical Summary for the Period ----, on file at Springfield Armory National Historic Site. These are semi-annual or annual reports covering the years 1951-1965.
SANHS	Springfield Armory National Historic Site. This refers to material held by the National Park Service at Springfield.
SFSA	Statement of Fabrications, Other Work Done..at National Armory, Springfield, Mass. Titles vary. These records, in RG 156/21, appear to be the only available summaries of annual operations c1865-93.

[1173] Ezell, "Death of the Arsenal System," pp. 7-12, 18-19, 35, Great Rifle, pp. 206-224; SAHS 1 January 1962 - 30 June 1962, p. 5, 1 July 1962 - 30 June 1963, p. 2, 1 July 1963 - 30 June 1964, pp. 1-3. 1 July 1964 - 30 June 1965, pp. 1-2.

Chapter 9

QUESTIONS OF ARMORY INFLUENCE

The varied influences of Springfield Armory on industrial practice, military weapons and procurement, or regional economy remain open questions. Many historians regard the Armory as one of the wellsprings of "Armory practice," a new system of manufacturing mechanisms in large quantities with machine tools to high standards of uniformity.[1174] Some recent work has called into question the preeminent importance of federal armories in stimulating mass production of interchangeable mechanisms.[1175] Little if any attention has been paid to the Armory's possible influence in the 20th century beyond its military role of making infantry weapons or providing assistance to private contractors.

This report focuses on the history of industrial practices and organization at Springfield Armory: the Armory's sometimes considerable influences on the society and economy of the Springfield region remain topics for future study. Evaluating Armory influences in the history of public or private industry requires both careful definition of influence, and sufficient documentation to allow for close comparisons. We have found that available case studies or syntheses meeting the latter criterion are rare, and generating such studies exceeds the scope of our efforts here. With these caveats, this chapter presents a brief review and some preliminary conclusions about the Armory's industrial influences.

[1174] E.g., David A. Hounshell, From the American System to Mass Production, 1800-1932, pp. 3-4.

[1175] Donald R. Hoke, "The Rise of the American System of Manufactures in the Private Sector," pp. 394-97.

A. Influence and Diffusion

The problems of documentation, and the variety of non-technical elements in Armory practice, make it clear that assessing influences on, or by, the Armory does not readily lend itself to "diffusion of technology" approaches.[1176] Springfield Armory practice involved far more than the use or management of mechanized methods, and included elements amenable to selective use--out of original context--by other manufacturers. Armory managers could also make selective adaptations of privately-developed innovations, weaving them into the peculiar texture of Armory practice. At any given time, manufacturing practice at Springfield Armory encompassed a wide variety of mechanized equipment, production methods, administrative regulations and customs, quality control procedures, and the accumulated skills of workers, shop supervisors, and higher-level Armory managers (Chapters 3, 6, and 7). Insistence on product uniformity dominated the evolution of manufacturing practice through most of the Armory's history (Chapter 3), contributing to many highly specialized practices and much reliance on "in-house" solutions to production problems. The high precision requirements of small arms manufacture, and a general reluctance to pay royalties on patented designs, only added to the importance of these solutions. Despite increasing reliance on methods and machines developed for private industry, a myriad of small, unpatented technical innovations by Armory employees remained critical elements in Armory practice through at least World War II (Chapter 7). Outside observers occasionally noted the potential value for other industries of some of these innovations, but many of these contributions--and their effects outside the Armory—remain undocumented.[1177]

In assessing influences in this context, it should be recognized that similarity between practices or

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[1176] E.g., in an important recent example of diffusion of technology study, the author first defined technology as embracing procedures; tools and machinery, patents, plans, or models; organization and management of production; and human skills, and then argued that in textile technology the mechanical elements eventually outweighed the human ones; see David J. Jeremy, Transatlantic Industrial Revolution: The Diffusion of Textile Technologies between Britain and America, 1790-1830s, p. 4. As we presented in Chapters 6 and 7, worker skills remained a paramount element in Springfield Armory technology until well into the 20th century. Any significant deskilling in small-arms making is a relatively recent phenomenon.

[1177] Fred H. Colvin and Ethan Viall, United State Rifles and Machine Guns, pp. 26-9, 97-8.

characteristics at any two factories, and the chronology of such similarity, do not of themselves demonstrate causality. Even if one rules out independent origins for similar practices, and assumes that something other than broadly-established customs or methods must define the relationship, many types of influence are possible. For each type of influence, there are one or more discrete mechanisms of diffusion. To demonstrate most types of influence, one would have to document the presence at Springfield of a practice, innovation, or method; a mechanism by which the practice was transferred to one or more specific industrial plants; and the use or modification of the practice by the other plants. Armory influence would be increasingly hard to determine as a practice passed through different generations or types of plants; ideally, one would pinpoint the first instance of transfer in such a series. Standards of evidence are necessarily less restrictive for more indirect types of influence, such as the stimulus of Armory purchases or contracts.

The simplest type of influence would involve original invention or development, and subsequent diffusion, from a single, known plant or firm. Given the skill and propensity of some Armory managers to modify or adapt innovations, however, Armory influence could also take the form of diffusing such modifications, which in themselves might represent significant advances. Cyrus Buckland's modifications of Thomas Blanchard's line of stock-making machinery are probably the best-documented example of this type of influence: it was Buckland's line which attracted wide attention.[1178] In both these types of influence, mechanisms of diffusion ranged from public reports or exhibitions to the individual movement of skilled men between factories and jobs. Many of the participants in the expansion of American manufacturing to the production of typewriters, bicycles, automobiles, and other mechanical products worked at the Armory at some point in their careers and carried with them knowledge of the methods used there as they went to other industries. As we discuss later in this chapter, however, this latter mechanism is especially hard to document.

Another direct type of Armory influence on private industry was through the purchases of tools, materials, and supplies. This influence derived from either the quantities purchased, or from specialized requirements for items that would not otherwise have been made or sold. More complex and harder-to-document types of influence derive from the Armory's long role as an information

[1178] For a summary of this case, see Carolyn C. Cooper, "A Whole Battalion of Stockers': Thomas Blanchard's Production Line and Hand Labor at Springfield Armory."

center, through which modified or unmodified innovations passed among private firms. During the period before 1840, when Springfield mandated exchange of information through the management of government contracts, it functioned in this role. After 1840, the Armory remained a ready public source of technical information until late in the 19th century, when the Ordnance Department became more secretive about its arsenals. Special-purpose visits by contractors, or by qualified observers like Fred Colvin and Ethan Viall trying to assist prospective contracts, became important beginning in World War I, and after World War II the Armory's ability to provide information to contractors was a major part of its mission. The information-center type of influence would usually assume relatively formal contacts between Armory managers and their counterparts in other domestic or foreign firms and government departments.

B. Patterns of Influence: Observations and Preliminary Conclusions

Armory Purchases

The scale of early 19th century Armory purchases were potentially important stimuli for developing industries. Examples include the purchases of gunstock blanks, iron, and files (Chapter 5). The Armory bought files in such large quantities that it became a significant customer of the file industry centered in Sheffield, England. In 1856, the Armory had 360,000 files on hand—an amount equal to 25% of the annual export of files from Sheffield to the United States at that time.[1179]

Among the most important of specialized Armory purchases were its orders for machine tools. We have seen that these began at least as early as 1818, when outside suppliers were attempting to provide the Armory with a satisfactory barrel turning lathe (Chapter 7). Armory purchases of machinery seem to have been particularly important for the Ames Manufacturing Company of Chicopee, Massachusetts, which manufactured machine tools for many armories and enjoyed a particularly close working relationship with Springfield Armory in the mid-19th century.[1180] The gunstocking machinery designed by Cyrus Buckland at Springfield Armory was made and sold by

[1179] Felicia J. Deyrup, Arms Makers of the Connecticut Valley, p. 193; Geoffrey Tweedale, Sheffield Steel in America, a Century of Commercial and Technological Interdependence, p. 162.

[1180] Merritt R. Smith, Harpers Ferry Armory and the New Technology, pp. 288290, briefly outlines company history.

the Ames Company to other armories; both surviving examples of Buckland's inletting machine were made by Ames and sold to the Enfield armory in England. The ability of the Ames Company to supply jigs, fixtures, and gages for the Enfield rifle to the British government in a short time was undoubtedly based on experience gained in making such items for Springfield Armory (see Chapter 3). This firm also acted as agents for Springfield Armory in the purchase of a gun-barrel rolling mill and the iron to use with it from English suppliers (see Chapters 5 and 7).

The direct influence of the Armory through the magnitude of its purchases diminished after the Civil War. The War left the Armory with a large stock of machines and supplies and, by the time that purchase resumed, small armsmaking had become a much smaller part of the manufacturing sector in the United States.[1181] There were, however, also important indirect, if less quantifiable, effects of Springfield machine tool purchases. The Armory's contribution to the international reputation of American methods in making firearms, beginning in the 1850s, probably helped later American sales of small armsmaking machine tools to domestic and foreign customers. This contribution grew in part from Springfield's role as a center for gathering and disseminating technical information. The British commissioners sent to the United States in the 1850s were able to see many aspects of American small arms manufacturing technology assembled and operating in one place at Springfield.[1182] This helped the subsequent placement of orders with machine tool companies, such as Robbins & Lawrence and the Ames Manufacturing Company, for machinery similar to that which was on view at Springfield. The machine tool industry that blossomed in the rain of purchases made by Springfield and other armories during the Civil War continued to sell arms making machinery. For example, the Pratt & Whitney Company made many specialized production machines for small arms making in the latter part of the 19th century and, while some were sold to Springfield, many more were sold to private arms makers and to the armories of foreign governments.[1183]

Armory Practice

[1181] E.g., Deyrup, p. 217.

[1182] Nathan Rosenberg, ed., The American System of Manufactures.

[1183] Charles B. Norton, American Inventions and Improvements in Breech-Loading Small Arms, pp. 323-337.

We turn now to new methods and procedures, developed at the Springfield, and commercial, armories that were subsequently adopted in other industries, and to the question of the influence of "Armory practice" on American manufacturing technology. The term "Armory practice" has never been precisely defined, and we have generally capitalized it throughout this report to emphasize that our discussion pertained to Springfield. Although the public and private armories eventually shared important features such as gage-controlled machining and filing of forged metal parts, they evidently differed in the extent of achieved interchangeability, methods of labor division, and contracting procedures.[1184] Although the point has never been thoroughly investigated, it appears that private arms makers making patent weapons did not pursue full interchangeability because of cost factors.[1185] In discussing Armory practice, then, we must distinguish Springfield Armory influences on private arms makers, and the collective influence of American small arms makers on other industries. Historians have seen developments at the armories as influencing American manufacturing industry in three different areas, namely, the technology of manufacturing applied to products other than small arms, the organization and supervision of work within the factory, and systems management including centralized purchasing and cost accounting. Machine tool makers and individual mechanics are often credited with being the vectors of diffusion.[1186]

Problems Evaluating Technological Influences

The major difficulty in demonstrating the influence of Springfield Armory in manufacturing technology is the nature of the data available. Much of the evidence adduced for the importance of Armory practice was obtained from authors such as Roe and Hubbard who produced industrial genealogies that trace the career paths of mechanics between employers.[1187] These are for the most

[1184] David A. Hounshell's far-ranging survey, From the American System to Mass Production, 1800-1932, in various places defines Armory practice as machine-made interchangeability (p. 43), as an Armory tradition of manufacture (p. 46), and as what the British came to call an American system of manufacture with gage-controlled machining not necessarily geared towards interchangeable manufacture (p. 49). In general parlance, Armory practice at best applied only to metalworking done with some precision; the fact that it was sometimes conflated with interchangeability was a beneficial marketing device for some American arms makers, notably Samuel Colt; see ibid, pp. 19-21.

[1185] Ibid, pp. 48-9.

[1186] Nathan Rosenberg, "Technological Change in the Machine Tool Industry."

[1187] Joseph W. Roe, English and American Tool Builders; Guy Hubbard, "Development of Machine Tools in New

part undocumented and seem to be based largely on reminiscences. Other, frequently used sources are business records that do not contain explicit information about manufacturing technology. We have seen (chapters 6 & 7) that some of these sources do not accurately describe actual manufacturing processes; they may be equally unreliable in tracing the spread of Armory practice. Material evidence has hardly been used at all.

Nineteenth century mechanics often moved frequently between different employers, and this was undoubtedly one of the most effective means of diffusing new manufacturing technology. However, the fact that a company employed someone who had formerly worked at Springfield or some other private armory does not automatically mean that armory methods were adopted by the new employer. Henry Leland, founder of the Cadillac Motor Car Company, worked successively at a loom builder's shop, the Springfield and Colt armories, and Brown & Sharpe before he entered the automobile business. He worked at Springfield as a toolmaker during part of the Civil War, and it is difficult to identify the influence of Springfield on his manufacturing skills.[1188]

The large excess capacity of government and private industry at the end of the Civil War also complicates tracing armory influence. The private armories attempted to turn this capacity to other products, naturally trying to maximize existing plants and equipment. Hence, "Armory practice" may have been used because it required the least capital investment rather than because of manufacturing advantages it offered aver alternative methods.

Interchangeable manufacture

Although at the core of Springfield Armory practice, mechanized, gage-controlled interchangeable manufacture[1189] did not originate at Springfield, was not limited to small arms making even in the early 19th century, and--at least to Ordnance Department standards--was not characteristic of private

England."

[1188] Hounshell, p. 81.

[1189] Essentially craft-based efforts at interchangeability, such as Honoré Blanc's in France and Simeon North's during the War of 1812 (Chapter 3), were important stimuli for this kind of work, but do not represent anything resembling even the narrowest definition of "Armory practice" which can be ascribed to public and private armories after 1830.

arms makers. John Hall and Simeon North achieved small arms interchangeability through the use of gages twenty years before it was accomplished at Springfield in 1849. Interchangeability was also attained earlier in other industries, such as clock making and machine tool building. By 1809 Eli Terry (b. 1772) was making wooden-works hang-up clocks at the rate of 3000 per year by assembling standardized, interchangeable parts. The clock mechanism and its constituent parts were designed to facilitate production, and were made on special-purpose machinery. For example, wheels (large gears) were made by turning a stack of blanks on an arbor, and then sawing in the teeth as the arbor was indexed to successive tooth positions. Gages that could be dropped over a part being turned on a lathe were used to check the progress of the work.[1190] Thus, Terry had in place at an early date many of the techniques that we associate with Armory practice, and was producing on a scale not much smaller than at Springfield (9000 muskets compared to 3000 clocks per year in 1809).

Interchangeable manufacture was also practiced in the metal working industries. In England, James Nasmyth began the manufacture of machine tools with interchangeable parts in 1836 at the Bridgewater Foundry (Manchester), which was designed for "flow-through" production.[1191] Nasmyth's production was on a large scale; for example, his firm turned out 236 crank-action shapers in 1836. Other British examples include Brian Donkin's Fourdrinier paper-making machinery made with interchangeable parts by 1832, Richard Robert's interchangeable spinning machine parts made with self-acting machine tools by 1835, and locomotives made by Roberts with a system of templates and gages in 1834 so that all parts of engines of the same class interchange.[1192] Thus it is not correct to think of interchangeable manufacture as being specially associated with the small arms industry, although it is probably true that the absolute level of precision attained in small arms mechanisms was higher than in these other products.

Aside from questions of cost, which perhaps inhibited some manufacturers such as Colt who might

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[1190] Donald R. Hoke, "Ingenious Yankees: The Rise of the American System of Manufactures in the Private Sector," Chapter 2.

[1191] J.A. Cantrell, James Nasmyth and the Bridgewater Foundry, p. 64.

[1192] Ibid, pp. 72-3.

otherwise have pursued interchangeability, manufacturers in some industries simply did not find interchangeability useful or necessary. The American textile machinery industry was in this latter group until late in the 19th century. Taking advantage of the often specialized designs needed by textile manufacturers, the machinery makers were able to monopolize repair and replacement-parts business by making their machines with non-standard parts. The Lowell Machine Shop, for example, began advertising interchangeable parts only in the 1890s, and then only for some machines.[1193] Other metalworking industries also valued assured repair business over interchangeability[1194]. The influence of the Armory on this type of industry was slight.

As with many Armory accomplishments, the commercial influence of Springfield interchangeable manufacture was probably not in originality or widespread acceptance, but in the scale and rigor of execution. It represented a standard of excellence with which other arms makers could associate, and which helped encourage the use of machine tools. Springfield Armory interchangeable manufacture may have also acted as a kind of pool of extreme industrial practice in which manufacturers could sometimes fish for new ideas or methods. These influences are at this time, however, highly speculative.

Forging and machining

The second major characteristic of Armory practice, forging of metal parts followed by machining and filing, was a direct evolution of basic smithing technology used to shape wrought iron parts from earliest times. Until machine tools that were sufficiently powerful to cut parts directly from stock-sized bars and plates were developed late in the 19th century, forging as closely as possible to final form was necessary wherever wrought iron was used in mechanisms. Most of the technological advances in forging and machining technology used at Springfield originated in the private sector. Barrel forging methods were developed by Asa Waters, milling machines by Simeon North and others at Middletown (see Chapter 7), and closed die forging by, among others, E. K. Root at the

[1193] George Gibb, The Saco Lowell Shops; Patrick M. Malone, "The New England Textile Industry and Mass Production."

[1194] Frank Stanley, "Old-Time Tools and Mechanics in a New England Shop," deals with a Connecticut pump-making firm which deliberately made screws with non-standard threads that no one else could reproduce.

Collins axe works and later at Colt's armory.

It is instructive to compare the progress made in mechanizing the manufacture of axes at the Collins Company and small arms at Springfield. Both products required the forging, welding, shaping, and heat treating of iron and steel parts, and initial mechanization occurred at both plants in the years 1830-1850. Both Collins and Springfield adopted anthracite for forge fires at about the same time, 1830. Welding with rolls instead of trip hammers was achieved at Collins in 1834[1195], and at Springfield in 1859 (Chapter 7). Springfield began to replace grinding with machining in 1818, when barrel lathes were first used, and made a major improvement in substituting milling for grinding in shaping bayonets in 1841 (Chapter 7); axe shaving was introduced at Collins in 1845.[1196] Both factories developed a systems concept, a sequence of machines each in sufficient numbers to permit a steady flow of work through the plant, in these years. Metallurgical technology was advanced at Collins in 1843 by E. K. Root's mechanized tempering equipment;[1197] at Springfield, experiments with the hydrostatic proof testing of barrels were carried on in 1848 (Chapter 8). Thus it seems that manufacturing technology was advancing at a similar pace at both these establishments, with the more difficult problems being solved somewhat later than the easier ones at each plant.

Application of "Armory practice" technology-to other products

Many parts of a sewing machine mechanism other than the cast iron frame are similar to parts in a gun lock. David Hounshell took study of sewing machine manufacture in the 19th century as far as documentary sources will permit.[1198] The three manufacturers that he studied—Wheeler & Wilson, Brown & Sharpe for the Wilcox & Gibbs machine, and Singer--all used forged parts (other than the frame), but seem to have used different proportions of hand filing and machining with the aid of jigs and fixtures. Wheeler & Wilson made extensive use of jigs and fixtures, and evidently attempted to

1195 Hoke, p. 134.

1196 Ibid, p. 148.

1197 Ibid.

1198 Hounshell, Chapter 2.

minimize the amount of filing used; Brown & Sharpe, in making the Wilcox & Gibbs machine, also invested heavily in specialized tooling. Singer used more hand fitting, thereby following somewhat more nearly the practice of the commercial armories. These decisions seem to have been influenced by considerations of availability of plant and equipment, and by personal preferences of the managers, rather than by any attempt to duplicate methods used at armories. It appears that only close study of material evidence from sewing machines can further address the questions of technological transfers and management decisions.

After the Civil War, excess arms making capacity was easily shifted to making sewing machine parts, as was done at the former Sharps Rifle plant in Hartford in making parts for the Weed sewing machine. This same manufacturing capacity was later applied to making bicycle parts by forging followed by machining.[1199] Some new manufacturing technologies that were unrelated to anything used in small arms originated in the New England bicycle industry, such as ball bearing making and precision grinding. It was in bicycle plants outside of New England, where there was no excess arms-making capacity to keep busy, that forming parts from sheet steel in place of forging originated. Springfield received no return flow of new methods for many years; we have noted that Springfield resisted the use of stamping methods for shaping metal parts until well into the 20th century (Chapter 7).

Another product having close similarity to the gun lock is the door lock. Linus Yale (b. 1821) made a series of inventions culminating in the pin-and-tumbler cylindrical lock, which improved the performance of locks and also facilitated lock manufacture. By the time that the Yale and Towne Company was organized in 1868, each part of the lock was designed so as to allow manufacture with machine tools.[1200] There is no discernable "Armory practice" influence in this development.

We have already noted that Springfield Armory expertise in the design and use of jigs and fixtures attracted attention during the era of magazine rifle production, especially as a result of Colvin and Viall's study (Chapter 7). It is presently impossible to evaluate the influence of this expertise, since

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[1199] Hubbard, pp. 171-3.

[1200] Siegfried Giedion, Mechanization Takes Command, pp. 51-76.

we lack both evidence of whether any firms applied Springfield jig and fixture methods directly, and much evaluation of Springfield's accomplishments in this field relative to those of other industries. Once again, the nature and extent of jig and fixture usage depended in part on the manufacturing objectives, and Armory insistence on interchangeability put them outside the industrial mainstream.

By the end of the 19th century, for example, the watchmaking industry had a system of jigs and fixtures in place that in some ways surpassed the system at the Armory. The extensive use of automatic machinery and mechanical transfer devices, and the simultaneous, precise cutting of large numbers of tiny parts set the best watchmaking firms, such as the Waltham Watch Company, apart from the rest of American industry. However, the selective assembly methods in use with some components at Waltham were unacceptable to a military that wanted full interchangeability of parts chosen at random. A former machinist at Springfield Armory helped set up the first production system for the Waltham firm in the 1850s, where developed a practice of selective assembly in making a Waltham watch. The assembler chose components "from the right boxes or jars." These finished components had been pre-sorted and placed in containers according to very precise distinctions in size, weight, or strength. Matching of watch parts in a delicate assembly involved careful selection instead of hand-fitting with a whetstone.[1201]

In reviewing the influence of "Armory practice," Donald Hoke asserts that such practice had limited influence in the private sector, and that all of the elements of the so-called American system were used outside as well as within the federal armories.[1202] Manufacturers adopted interchangeability where it was economically useful in making clocks (before 1820), watches and typewriters (by the 1870s). We have also seen that it was being adopted in the 1830s in England where it was seen to be useful, as in machine tools and locomotives. The manufacturing innovations that took place in each of the industries that Hoke studied resulted in large reductions in the sales prices of goods. He saw the federal armories as insensitive to changes in product design that would facilitate manufacturing; there was little transfer of technology from the armories to other industries beyond the general concept of a production system based on close control of dimensions through gaging and

[1201] David Landes, Revolution in Time, pp. 314-16.

[1202] Hoke, p. 394.

inspection.[1203] He concluded that the importance of the federal armories was that they demonstrated that large scale production to established specifications was possible; this seems to have been the inspiration behind the formation of the Waltham Watch Company, for example.

Our study supports all of these conclusions. We would add that in the first quarter of the 19th century, purchases of arms by the federal government allowed entrepreneurs such as Eli Whitney, Simeon North, and Nathan Starr to specialize in one product to a greater degree than was possible for manufacturers selling in commercial markets. This specialization probably accelerated the development of machining and gaging technology.

Organizational Influences of Springfield Armory Practice

Through the 19th century, the major components of Springfield Armory factory management were: an absence of inside contracting; extensive piece-rate payment of most employees with a fine-tuned but flexible division of labor; extremely detailed accounting of raw materials and finished work; organization of shops by process or type of work; 100% inspection of finished components; and considerable, though not final, control of finished-work inspection and materials requisitions by shop foremen (Chapters 4, 5 and 6). This was, then, decentralized shop management, closely controlled and coordinated through accounting requirements and a few skilled managers above the shop level. A dearth of ordnance officers and dependence on skilled workers tended to limit military control of peacetime Armory operations, except in some matters of worker decorum and hours of work. The effectiveness of this system is reflected in the general absence of labor strife, and the ability of the Armory to meet most Ordnance Department production requirements over a very long period of time. We found that the only substantial 20th-century change in organizational practice was removal of requisitions and inspections from the control of the foremen, and centralized planning and routing of jobs; most other management changes appear to reflect only bureaucratic reshuffling as the Ordnance Department disappeared into a much larger United States Army, beginning with the preparations for World War II.

The 20th-century changes in centralized control emerged from the application of scientific

[1203] Ibid, p. 397.

management techniques within the Ordnance Department, c1905-17. Springfield otherwise partook little of this controversial program. The Armory's organizational peace through this period, when some other department arsenals experienced upheaval, is an additional indication of a well-developed and effective organizational structure. As noted in Chapter 6, in fact, the Chief of Ordnance during this period praised the Armory's independent, long-term development of management procedures. Although much of this development predated explicit formulation of management programs by Frederick Taylor and his associates, there is at present no evidence that Springfield Armory provided any direct influence on Taylor's work.

Alfred Chandler credited the Armory with being an important source of factory management techniques.[1204] We simply do not know if American industry tapped into this "source" in any way which could be construed as direct or indirect influence, largely because most descriptions of historic firms provide little detail on organizational approaches. As we note in Chapter 10, Springfield's organization was probably unique among early 19th century factories, for the extent of its manufacturing controls and recordkeeping relative to its size. As with so many elements of Armory history, however, these unusual features derived from Springfield's largely independent response to its particular mission within the Ordnance Department. The fact that Armory management procedures resembled or presaged those of some later 19th and 20th century firms is of itself no proof of Armory influence. It should also be noted that if, as is often argued, the evolution of industrial management was towards greater control over workers[1205] then Springfield Armory was not typical. The dense forest of Armory accounts and receipts hid a system where worker skills and relatively numerous shops restricted the development of extensive central authority on a day-to-day basis.

There are very few industries other than textile mills and the armories for which the character of artificer's work in the 19th century has been studied. Thomas Leary's study of the Davis & Furber Company, makers of textile machinery, allows us to make a number of comparisons with Armory

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[1204] Alfred D. Chandler, Jr., The Visible Hand: The Managerial Revolution American Business, pp. 72-5.

[1205] E.g., Daniel Nelson, Managers and Workers: Origins of the New Factory System in the United States, 1880-1920.

work in the period 1830 to 1860.[1206] Making textile machinery in the early 19th century involved new requirements, such as making drawing rollers, which were not easily met by craft methods. There was a shortage of artificers capable of making textile machinery just as there was for arms making. By the time that machine tools such as lathes and gear cutting machines were common in the Davis & Furber shop, machinists were an important component of the workforce and worked on a variety of tasks: in 1839 there were about 20 lathes and 40 workmen in the shop, with about half the workforce being machinists. In comparison, at Springfield only about 10% of the artificers were doing machine work at this time (see Table 6.6 in Chapter 6). However, the capital invested per worker seems to have been much greater at Springfield, $2,908 per artificer in 1845 compared with $384 per worker at the North Andover Shops.[1207] Leary put together biographical sketches of a number of the artificers employed at Davis & Furber at this time. There was a great variation in the educational backgrounds of these men; some were barely literate while others had had substantial schooling. Most had moved through a variety of jobs at the start of their careers. We suppose that the educational level and mobility both contributed to the learning of new ways of working that was so essential to industrial growth in this period. Except for the smaller size of the shop, it seems unlikely that the work experience at Davis & Furber was very different from that at Springfield in terms of the tasks to be done or the methods of doing them.

[1206] Thomas E. Leary, "The Labor Process in an Early Textile Machine Shop: Workers at the Davis & Farber Company of North Andover, Massachusetts."

[1207] Ibid, p. 92; Deyrup, p. 220.

Chapter 10

SIGNIFICANCE AND ACCOMPLISHMENTS OF THE SPRINGFIELD ARMORY

The Springfield Armory was a major force in United States Army shoulder arms procurement for nearly 175 years, and acted as the Army's principal small arms supplier from the Civil War to the end of World War II. In the first few decades of the 19th century, the Armory was one of the largest metalworking establishments in the United States, so that developments there inevitably had national significance. The factory system of producing metal goods originated at Springfield, and was selectively adapted by some other industries. As other manufacturing industries grew, the presence of the Armory in American manufacturing necessarily became smaller. The Armory workforce, as a fraction of the total labor force in United States manufacturing, decreased by a factor of five between 1810 and 1840 and another factor of ten by 1870.[1208] After 1850, other industries eclipsed the Armory in both size and influence on manufacturing technology. The Armory's greatest impact on the national economy was in the first half of the 19th century. Thereafter, it continued to make important contributions to Army capabilities, but was no longer one of the fountainheads of American manufacturing technology or management. This final chapter provides some perspective on Armory accomplishments.

A. Small Arms Production

The Springfield Armory successfully supplied the small arms requirements of the United States

[1208] Stanley Lebergott, Manpower in Economic Growth: The American Record Since 1800, Table Al; Felicia J. Deyrup, Arms Makers of the Connecticut Valley, pp. 5-7.

Army, with only occasional lapses, from 1794 to 1963, acting sometimes in concert with other federal armories or private contractors, and sometime alone. In the years before the Civil War, production of small arms in federal establishments was supposed to be divided about evenly between Springfield and Harpers Ferry. However, Springfield almost always achieved both higher production and lower unit costs than its sister factory. Production and cost data are available for both armories; to take a year (1835) in which the number of armorers was the some (229) at both places, Harpers Ferry made 10,000 muskets at a cost of $15.89 each, while Springfield made 13,000 muskets at $12.44 each.[1209]

In the Civil War, Springfield achieved remarkable feats of production and delivered more rifle-muskets than all private contractors put together (805,538 to 643,439).[1210] The production of 276,200 rifle-muskets in 1864 represented a twenty-fold increase over the average annual rate of the previous decade. The Armory used its existing production system to attain this increased output, which is evidence of the effectiveness of both the design of the system and the efficiency of the management. The increase was obtained with little direct preparation before the war. However, it did fall to the private armories to supply all of the breechloading and repeating rifles and carbines used by the Union. Although the newer designs had relatively little impact in most campaigns, this war clearly demonstrated the potential of such weapons for future military use.

The Armory greatly increased its production rate during the Spanish-American War, but the duration of this conflict was too short for a significant jump in Krag rifle availability.

Springfield Armory's greatest failure in meeting Army weapons needs was in World War I, when Winchester and Remington supplied most of the rifles used by American soldiers. During this war, Winchester made about 470,000 and Remington another 1,700,000 M1917 rifles, while Springfield made about 270,000 M1903s. The low production of M1903s reflected problems with both Armory manufacturing technology, and management problems that must be ascribed to the Ordnance Department rather than to the Armory. Although Armory plant and operations were significantly improved in the pre-war years, the scale of manufacturing was insufficient to allow for the

[1209] Deyrup, pp. 229, 233; Merritt R. Smith, Harpers Ferry Armory and the New Technology, Table 1.

[1210] Deyrup, p. 183.

enormous infantry forces deployed in Europe.

Extensive manufacturing preparations in the 1930s, and careful M1 rifle design attuned to production requirements, allowed for enormous World War II rifle output. The Armory's contributions to American military efforts were greatest in this war, and in the Civil War. Given the production engineering problems and radical new design of the M1, Springfield's manufacture of more than three million rifles based on about five years preparation was an astonishing accomplishment. It seems likely that relatively few private manufacturers could have equaled this feat. Production of the first standard-issue semi-automatic rifle also gave United States infantry forces significant advantages in many battles. Springfield supplied most of the M1s used by the Army and Marine Corps, with a much smaller number made by Winchester, although the private firm also made the M1 carbine.

Redefinition of Armory manufacturing standards was partly responsible for the successes of World War II. Difficulties arose when the Springfield Armory renewed M1 production during the Korean War, in part because of a return to very narrow manufacturing tolerances. The relative brevity of this conflict, and the large number of available M1s stored after World War II, diminished any negative effects of Armory performance.

In the first two-thirds of the 19th century, the United States did not possess sufficient private industrial capability to meet Army small arms needs. Such industrial capacity was still not in place during the Civil War, although privately manufactured rifle-muskets equaled about 75% of the total made by Springfield Armory. Even in the 1860s, however, private firms showed much greater facility for turning out new weapon designs than federal armories. By the beginning of the 20th century, the American industrial base was large enough to supply all the small arms that the Army could use, requiring other justifications for continuation of the Armory. For about forty years, Armory and Ordnance Department managers maintained that Armory efficiency, low costs, and quality were critical for Army small arms, but the world wars clearly indicated a need for private supply of most weapons types to much larger armed forces. Despite the Armory's demonstrated ability to supply some of the growing class of small arms, the post-1945 commitment to private supply deprived Springfield Armory of its major mission, and led to a rapid shift in Armory

priorities emphasizing research, development, and prototype production. Diminished Ordnance Department support for the Armory contributed to the end of Springfield weapons production very early in the Vietnam War, before the entry of large American forces.

B. Research and Development

Pre-Civil War small arms development was incremental and somewhat sporadic. Springfield Armory did not contribute to the most important early 19th century changes--percussion ignition, the Minié ball, rifling, and the Maynard primer--although it played a part in adapting some new developments for Army use. By the 1860s, the Armory was heavily involved in testing alternative designs of breechloading, and, later, repeating rifles. The Armory set up production lines and made short runs for several rifles of interest to the Army and the Navy. Thus, Springfield Army turned its significant versatility in production technology to development tasks, although it appears that Armory capacity in this regard differed little from that of many contemporary private armories.

The Krag rifle, adopted in 1892, was a design to which the Armory had made little if any contribution, reflecting a relative lack of progress in Springfield weapons development. The conservatism of both Army field officers and Armory production managers limited dramatic design changes through the 19th century. Stung by imposition of the foreign model, and challenged by radical new production requirements, Armory officers and mechanics re-designed the Krag several times. The Spanish-American War demonstrated important limitations in the Krag, and led to development of the M1903 rifle, which was based on an Armory re-working of the Mauser design already in use by European armies. The M1903 included some Springfield innovations, but essentially represented incremental advances in both design and manufacture at which the Armory excelled. In this sense, the M1903 culminated nearly ninety years of Armory practice. It proved to be an extremely well-made and effective weapon, allowing the Army to field a bolt action magazine rifle at least the equal of any in the world.

The design of the M1 was the single most significant arms development undertaken at Springfield Armory, giving the Army a self-loading weapon that could be produced in quantity, while other World War II infantries were largely armed with bolt action rifles similar to those in use in World War I. The success of this project seems more attributable to John Garand than to any Armory

strengths in research and development. Garand seems to have worked more as an individual inventor and production engineer, who happened to be located at Springfield Armory, than as a member of the Armory organization. The Armory as a whole contributed more to production than to the design of the new rifle, although even in production design Garand's strengths were often critical.[1211] Only with the threat to the Armory's traditional mission, posed by the growth of private arms procurement in World War II, did Springfield emphasize research and development.

The late 19th century adoption of smokeless powder for small arms led to increased demands on the strength and erosion resistance of steel used for barrels and actions. Metallurgical testing became increasingly important at Springfield Armory, beginning in the 1890s, with the Armory following established industrial practice. Failures of bolts and receivers in the early production M1903s illustrates the tardy emergence of proper metallurgical control over Armory products, many of which were case-hardened. Springfield did not correct this particular problem with double heat-treating until c1918. The laboratories of the Metallurgical Division, established in World War I to control materials testing, contributed to new weapons designs but remained largely an arm of manufacturing. Metallurgical research and development became a much more important part of the Armory mission after 1945, and projects such as the development of new methods of making small parts by precision casting were in progress at the time of closure.

Armory ballistics tests began in the 1850s and continued thereafter. The Armory did not become the center for small arms ballistics research for the Ordnance Department, however, and appears to have followed established industrial practice in this area.

Through the greater part of its history, the principal research and development contribution of the Springfield Armory was in creating manufacturing systems that could deal with the introduction of new weapons, and with the rapid expansion of wartime production. It was only in World War I and in the Korean War that this system failed. The M1 Garand rifle was an extraordinarily important, but isolated, instance of a completely new weapons design emerging from the Armory.

C. Manufacturing Organization

[1211] e.g., Julian S. Hatcher, The Book of the Garand, p. 117.

Some economic historians see the Springfield Armory as the American origin of factory production of standardized, high-precision metal goods.[1212] Other American industrial products, such as textile machinery and clocks, emerged on a large scale by the period of Armory florescence beginning c1815, but Springfield's manufacture of uniform small arms was probably unprecedented before 1860 for the scale and complexity of manufacturing organization. Several major features characterize the factory production system:[1213]

> division of labor around a rationalized progression of tasks;
>
> organized production with centralized, close supervision that controls the flow of materials, supplies the tools, and sets the schedules for work throughout the entire organization;
>
> centralized control of the quality of work, permitting the manufacture of a uniform product and the payment of piece rates to artificers.

Springfield Armory's principal contributions to manufacturing organization relate to the latter two features, both of which emerged in response to the drive for uniformity. Quality control to attain product uniformity was a goal set by the Ordnance Department and executed by Armory management. Uniformity was an Ordnance Department ideal which did not require much intradepartmental economic justification; it clearly simplified the deployment and supply of troops, and also served to enhance the central authority of the department over arsenals and contractors.

The most notable management innovations made at Springfield to achieve uniformity were close supervision of labor and production, and extensive recordkeeping. Together, supervision and records allowed for effective introduction of 100% inspection of parts made at each successive stage of production, which in turn allowed for the large scale adoption of piece work because artificers could be paid only for acceptable completed work. These methods, developed at Springfield for other than economic reasons, later proved useful and economical to some private entrepreneurs when they organized their own factories on a piece-work basis.

The relative amounts of labor devoted to administration and supervision of production at the

[1212] Alfred D. Chandler, Jr., The Visible Hand: The Managerial Revolution in American Business, pp. 72-5.

[1213] e.g., Andrew Ure, The Philosophy of Manufactures, 3rd ed., p. 13.

Armory are shown in Table 10-1. Both administration and supervision show a general upward trend throughout the 19th century, with declines during periods of wartime production (showing that the Armory staff could successfully supervise a much expanded workforce), and increases during slack periods (when the number of production workers was reduced). Data for other industries with which these figures can be compared are sparse, but for large-scale, late 19th century American industries it appears the Armory had a relatively high level of supervision and administration. In 1900, foremen were 1.5% of the workforce in American manufacturing; the contemporary Armory had several times this percentage of supervisors.[1214]

Table 10-1

Administrative and Supervisory Manpower at Springfield Armory

Yea r	Administration	Supervision
1811	1.4%	2.7%
1820	2.3	3.6
1850	1.7	4.3
1860	4.0	10.6
1864	1.3	3.6
1878	6.4	9.2
1898	3.5	4.1

Percentages calculated on basis of total number of production workers. Data flow Springfield Armory work returns and payroll records. "Administration" includes the superintendent, clerks, and messengers; "Supervision" includes the master armorer, assistant master armorers, and foremen.

Supt. Alexander B. Dyer's 1863 summary of Armory manufacturing needs provides another indication of the level of expected supervision: for 1,446 production workers, Dyer listed 160 supervisors and inspectors, 11% of the workforce.[1215]

[1214] Lebergott, Historical Statistics of the United States.

[1215] Major A.B. Dyer to Brig. Gen. G.D. Ramsay, February 4, 1864, in U.S., Ordnance Department, A Collection of Ordnance Reports and Other Important Papers Relating to the Ordnance Department, Vol. III, p. 877.

There is little doubt that the Springfield Armory kept more extensive records on all operations than any comparable 19th century American industrial organization. Some of this recordkeeping responded to Ordnance Department needs for maintenance of central control, accounting of supplies and products, and reporting to Army and Congressional authorities. These needs alone do not justify the extraordinary detail of Armory records, and it is not always clear had all these records were used in the management of Armory operations. The most important explanations for the voluminous data in payroll and work returns appear to be maintenance of the piece rate system, and related control over the productivity of a large workforce, by transferring continual inspection results into monthly tallies. Piece rates at Springfield were defined by dividing expected daily numbers of completed tasks into the management's definition of a fair daily wage. Comparing actual to expected output and payments allowed for centralized Armory management analysis--from one set of records--of individual performance and the relationships of piece rates to real wages. Several important episodes in wage or rate adjustment would have been impossible without such records.

Armory management of detailed production controls with few serious labor disputes was a significant accomplishment. Factors contributing to labor peace were relatively good wages, generally steady employment (except in wartime), a gradual evolution of factory-type production retaining strong needs for highly skilled labor, and worker access to Congressional intervention. The insulation of the Armory from the successive financial panics that often disrupted private manufacturing operations in the 19th century also made it a desirable place to work, enhancing the ability of the Armory to act as a reservoir of technical experience and know-how.

D. Mechanization

During Roswell Lee's superintendency (1815-1833), the Armory was the central point of information exchange on new methods and machines between different arms makers in the United States; this role continued as long as the system of purchasing contract arms lasted. During the years before the Civil War, Springfield adopted mechanical innovations for mechanized production developed by individual inventors, and incorporated these into its production system. Most of these inventions and developments originated outside the Armory, although some Armory mechanics like Cyrus Buckland made important contributions. Before there was an organized American machine tool industry, Springfield played a very important role in exchange of information on, and

incremental improvement in, manufacturing methods. Specialist machine tool builders began taking over this function, one of the most critical in the development of manufacturing technology, by the 1850s.[1216]

Three factors contributed to the Springfield Armory's success as a reservoir and dissemination point of technological expertise: its size, the continuity of its operation, and the role of government contracts in formative American armsmaking and machine tool industries. As noted, the Armory was free of economic fluctuations caused by the panics and currency problems that plagued 19th century American entrepreneurs. Managers at the Armory made a point of keeping informed about new private arms making developments in metallurgy and in manufacturing technology. Often, the Armory was able to recruit skilled artisans from these plants. Information and advice was given freely to manufacturers who needed help with technical problems, and similarly received from manufacturers interested in obtaining or completing federal arms contracts. Free exchange of information among the different armories is one of the most remarkable characteristics of the industrial climate of the early 19th century in the United States. We believe that an important cause of the flowering of industrial innovation in New England in the first 50 years of the 19th century was the particularly effective mix of strongly-interacting private and public manufacturing organizations, stimulated by federal military procurement.

On the other hand, we find a much higher level of inventive activity at the smaller, private plants. The areas around Millbury, Massachusetts (point of origin for new forging technology and irregular turning), and Middletown, Connecticut (first interchangeable manufacture, milling machinery), were particularly prolific sources of new manufacturing technology. These plants may have been less encumbered by bureaucratic requirements than the federal Armories, although Armory superintendents had great latitude in selection and application of new methods. Even when innovations originated at Springfield, they were sometimes created by individuals, such as Thomas Blanchard and John Garand, working largely independently of the Armory organization.

We recognize three types of mechanization at Springfield. In type I, power is used to reduce the physical labor in tasks that could nevertheless be done by hand; in type II, machinery is used for

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[1216] Nathan Rosenberg, Perspectives on Technology, Chapter 8.

tasks that cannot be done in a satisfactory way by hand; in type III, fixtures, power feed, and automatic control of machines are used to reduce the labor in, and increase the rate of, mechanized production. Armory managers introduced both type I (trip hammers, hollow milling, and pan boring) and type II (barrel turning) in the years before 1820. Between 1820 and 1830, Thomas Blanchard introduced type III mechanization of some gunstocking work. Subsequent Armory advances included the milling of plane and curved surfaces in the 1830s, profiling machines in the 1840s, and rifling machines in the 1850s. Thus, by the mid 19th century, the principal components of armory mechanization were in place. Nevertheless, the replacement of hand work by machines came slowly in the arms industry and, at Springfield, was still underway through the first third of the 20th century.

The only prominent employee designers of production machinery at Springfield in the 19th century seem to have been Thomas Warner and Cyrus Buckland. Warner in 1834 developed a machine for milling the flat surfaces of lock plates. Buckland's importance is shown by Ames' stipulation in 1854 that the Ames Manufacturing Company could not undertake to make the stocking machines for the Enfield Armory ordered by the British Commissioners without "... the co-operation and assistance of Mr. Buckland, Engineer at the United States Armory, in designing the ... machines."[1217] After mid-century, commercial builders such as Ames, and Robbins & Lawrence, supplied machine tools formerly built at the armories and, at the same time, became the principal agents in the development and dissemination of new manufacturing technology.

Most of the new machinery adopted by the Armory was first developed by entrepreneurs in the private sector. Before the Civil War, such borrowings included, for example, trip hammers for barrel welding (adopted in 1815 and originated by Waters), the barrel turning lathe (1818, Springfield Manufacturing Company), stocking lathe (1820, Blanchard), plain milling (1834, armories in Middletown), milling curved surfaces (1835, Robbins & Flagg), profiling (1848, Howe at Robbins & Lawrence), and barrel rolling (1859, England). During the magazine rifle era at Springfield (1892-1918), the Armory continued to buy new machines for such tasks as barrel drilling and rifling from the Pratt & Whitney Company. Use of commercial technology accelerated greatly at Springfield after World War I. While tooling up for production of the M1 rifle, the Armory greatly

[1217] Nathan Rosenberg, ed., The American System of Manufactures, pp. 102-3.

extended the use of broaching technology. By this time, Armory technical efforts were dwarfed by those of other American industries.

While the general success of Springfield small arms production relied heavily on assiduous borrowings, it would have been impossible without continued and often gifted development of jigs, fixtures, and other mechanical adaptations to increase machine tool productivity. Incremental, in-house advances of this type culminated in production of the magazine rifles at Springfield. The importance of these innovations for American industry is at present difficult to gage, but they may have contributed in many small ways to a variety of private manufacturing achievements.[1218]

The most important design of a new manufacturing technology that can be attributed to the federal armories is the introduction of gages for dimensional control during manufacture. Both documentary and artifactual evidence of the gaging systems used in the private armories is very scarce, but we believe that gaging technology was most highly developed at the national armories. For example, both Nathan Starr (in 1828) and Lemuel Pomeroy (in 1829) borrowed gage sets from Springfield to help set up their own quality control systems.[1219] The relative contributions of John Hall, Simeon North, and Springfield Armory staff to the development of the comprehensive system of gaging in place by about 1840 may never be fully sorted out, but it now appears that gaging technology later adopted in other metal-forming industries originated at the federal armories. The Ames Manufacturing Company undertook to supply gages based on these principles on a commercial basis in the 1850s.

E. Procurement Standard for Small Arms

During periods before World War II when the Army relied on private contractors for some of its small arms requirements, the national armories provided production and cost standards to maintain quality and assure reasonable prices. Springfield was more important than either Harpers Ferry (in the 19th century) or Rock Island (in the early 20th century) in serving this function. Because of its superior technical capabilities and long continuity, it provided better measures of quality and price for small arms than were usually available from the other two federal manufacturing armories.

[1218] Patrick M. Malone, "Little Kinks and Devices at Springfield Armory, 18921918," pp.71-2.

[1219] Deyrup, p. 90.

Providing technical support to contractors was an important part of this role as a procurement standard, since obtaining acceptable small arms at good prices required assurance that contractors had effective manufacturing methods. We have just reviewed the important implications of this Springfield Armory mission for early 19th century American manufacturing development.

By the 1850s, the procurement role became an explicit argument for the retention of the national armories. The Secretary of War rebutted calls for the wholly private supply of military small arms by citing the need for federal arms design and production as a basis for control of contractor prices. At Springfield after the Civil War, this mandate evolved into a responsibility for evaluation of private and foreign small arms designs, although the authority of the Armory for such evaluation was never paramount within the Army.

From 1815 to 1830 the national armories provided inspectors and model arms to contractors, and so had to train inspectors and manufacture gages and pattern weapons. After 1830, Springfield gradually began to supply contractors with gages for use in both production and inspection. The Armory apparently performed this function well, especially after the introduction of a comprehensive gaging system within its own plant. Probably because most of its advances in mechanization at Springfield were borrowed from private industry, the Armory was, however, not always able to provide the best manufacturing standards for contractors. Private makers of the Hall and M1841 rifles apparently achieved fully interchangeable manufacture, including interchangeability among rifles made at different private armories and Harpers Ferry, before Springfield reached the same point to the satisfaction of its own mechanics in 1849. Springfield Armory performance of the procurement standard mission thus appears to us to have been somewhat uneven. It is important to note, though, that direct involvement of the Armory with contractors diminished during the 1840s, and neither of the two rifles mentioned previously were made at Springfield.

It is also unclear whether the interchangeable manufacture achieved by others in the 1830s had much bearing on practical means of large-scale production, or whether similar achievements claimed during the 1840s involved in-house manufacture of all components as was the case at Springfield.

In the Civil War period the Armory supplied the gages and inspectors needed to examine the output of the private contractors making rifle-muskets of the Springfield pattern. After the Civil War, small arms developed by numerous inventors were judged against those made at Springfield and grounds for rejection usually found. This appears to have inhibited arms design for the United States Army for several decades; in this period the standards function of the Armory served as a tool for the Ordnance Department to use in avoiding unwanted changes. From about 1850 to the early 1890s, the staff at Springfield was evidently satisfied with its own products and acted as a negative factor in innovation. Once the goal of uniformity was attained to the satisfaction of the Ordnance Department, resistance to change set in and persisted until the rifles used by the United States Army became obviously inferior to those used by other armies.

In World War I, the Springfield Armory failed as a standard against which to judge the work of other arms makers because the rifle it had designed and tooled up for could not be produced in adequate quantities. By this time, the divergence of Armory and commercial practices was too great to resolve rapidly in an emergency. As a result, most American soldiers and marines fighting in Europe were armed with weapons made by private contractors not of the Springfield pattern. This situation was reversed in World War II, when Springfield established a standard of quality and production for Winchester, the other maker of the M1, to emulate.

World War II also began a reversal of the Armory's role as a procurement standard. Although still responsible for small arms plans and specifications, and technical assistance to private manufacturers, commitment to private procurement after 1945 also made the Armory emphasize pilot production for the first time. Springfield had to engineer production methods which melded well with commercial practice. Because of both limited Ordnance Department support and Armory commitment to M1-era technology, Springfield's achievements as a procurement standard after World War II appear mixed. In the only example reviewed in any detail for this report, M14 pilot production succeeded at the Armory, but did not translate into effective private manufacture; a completely separate effort by TRW was required for large-scale commercial M14 production. In general, the post-1945 Armory was no longer a model for production efficiency.

F. Training

Our study of the mechanization of production at the 19th century Springfield Armory has shown that the development of artificer's skills was just as important as the development of new machinery to the advance of manufacturing technology in the United States. For the most part, the new manufacturing processes adopted by the armories represented incremental improvements made by a large number of artisans skilled in the mechanical arts, many as yet unknown to us by name. At the same time that new machinery was being introduced, higher demands were being placed on the traditional mechanical skills, such as precision filing, and the demand for artificers with these skills was increasing rapidly. All of these factors mean that the acquisition of superior mechanical skills by a growing workforce was a critical component of American industrialization in the 19th century.

We see two separate aspects to this learning process. One involved the learning of new skills by artisans already versed in traditional methods of working. Such skills would be, for example, those needed to set up a machine or to repair its cutting tools when worn. The other is imparting essential mechanical skills to inexperienced workers so as to enlarge the pool of artificers. This latter task was eased by the division of labor, illustrated by Simeon North's statement:

> I find that by confining a workman to one particular limb until he has made two thousand, I save at least one quarter of his labor...[1220]

However, the steadily increasing standards of precision required to attain interchangeability exacerbated training problems. As we have seen, filers were the most highly paid artificers at Springfield at the middle of the 19th century. In view of the importance of building up a supply of skilled artificers to the early industrial development of the United States, it is remarkable that the Springfield Armory did relatively little in a formal way toward training artisans. Apprenticeship programs were in effect briefly at several times, but were abandoned. In contrast, apprenticeship was common at the private shops, such as that of Robbins & Lawrence. We infer that informal training was practiced in the Armory shops, but have little evidence of its extent. The Armory recruited many of its most skilled men from private armories and, when a large increase in the number of artificers was required for successive episodes of wartime production, was able to draw them from the pool of industrial labor in the Springfield area.

[1220] S.N.D. North and Ralph North, Simeon North, First Official Pistol Maker of the United States, p. 64.

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INDEX

This index includes proper names, events, and same manufacturing materials; readers are referred to the detailed Table of Contents for topics or aspects of manufacturing, e.g., gaging, interchangeability. Army officers are listed with their highest known ranks.